March 1996
NSRP 0463

SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Impact of Recent and Anticipated Changes in Airborne Emission Exposure Limits on Shipyard Workers

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
Peterson Builders, Inc.

Report Documentation Page					*Form Approved* *OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE **MAR 1996**		2. REPORT TYPE **N/A**			3. DATES COVERED **-**
4. TITLE AND SUBTITLE **The National Shipbuilding Research Program, Impact of Recent and Anticipated Changes in Airborne Emission Exposure Limits on Shipyard Workers**					5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)					5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230-Design Integration Tower Bldg 192, Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**					8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**115**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

DISCLAIMER

March 1996
NSRP 0463

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

IMPACT OF RECENT AND ANTICIPATED CHANGES IN AIRBORNE EMISSION EXPOSURE LIMITS ON SHIPYARD WORKERS

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION, NAVAL SURFACE WARFARE CENTER

in cooperation with
Peterson Builders, Inc.

March 11,1996

Impact Of Recent And Anticipated Changes In Airborne Emission Limits On Shipyard Workers

Report Prepared By:

The Navy Joining Center
and
A Navy/Industry Task Group

For:

The National Shipbuilding Research Program
Society of Naval Architects and Marine Engineers
Ship Production Committee
Welding Panel SP-7

ACKNOWLEDGEMENTS

This report concludes a project managed and rest-shared by the National Shipbuilding Research Program under the Carderock Division, Naval Surface Warfare Center Contract NOO167-95R(.XI0248. The program is a cooperative effort of the United States Navy and the United States Shipbuilding Industry. Industry direction is provided by the Society of Naval Architects and Marine Engineers, Ship Production Committee Welding Panel (SP-7), chaired by Lee G. Kvidahl. The Project Manager is Harvey R Castner of the Navy Joining Center, U.S. Navy Center of Excellence.

In addition to the participating organizations listed below, funding for this work was provided by: the Navy, PMS-450T4, New Attack Submarine Program Ofiice; the Navy PMS 312-M, /Aircraft Carrier Program Management Office; the Navy, PMS 400D3, AEGIS Program Office, Destroyer Division; and the Navy Joining Center under the Navy Manufacturing Science and Technology program.

The partiapation of the following organizations in this project is acknowledged:

Chief of Naval Operations (Environmental Protection, Safety Occupational Health Division)
Naval Sea Systems Command
Navy Environmental Health Center
Naval Surface Warfare Center, Carderock Division
Naval Medical Research Institute
Naval Air Systems Command
Naval Facilities Engineering Command
Army Center for Health Promotion and Preventive Medicine
Norfolk Naval Shipyard
Bath iron Works
General Dynamics, Electric Boat Division
Newport News Shipbuilding
Navy Joining Center, Edison Welding Institute
University of New Orleans, Gulf Coast Regional Maritime Technology Center
National Center for Excellence in Metalworking Technology, Concurrent Technologies Corporation
B00z-Allen & Hamilton
American Welding Society

The following individuals are acknowledged for their participation in the project and preparation of this report Mr. Charles L Null, Naval Sea Systems Command, Arlington, VA; Mr. John Bishop, Navy Environmental Health Center, Norfolk VA; Ms. Joy Erdman, Chief of Naval Operations Environmental Protection and Safety Division, Arlington VA; Mr. Paul Bureau, General Dynamics, Electric Boat Division, Groton CT; Mr. Kent Shoemaker, Newport News Shipbuilding, Newport News, VA; and Mr. Chris Lonie, Booz-Allen & Hamilton, Arlington VA

Table of Contents

List of Tables

List of Figures

1.0 SUMMARY

The Navy and the National Shipbuilding Research Program Welding Panel (SP-7) are concerned with the recent and anticipated future reductions in Occupational Safety and Health Administration (OSHA) and American Conference of Governmental Industrial Hygienists (ACGIH) worker exposure limits for airborne emissions. These changes involve nickel (Ni), manganese (Mn), and hexavalent chromium (Cr(Vl)). The concerns are due to the potential impact these reductions may have on operations in Navy facilities, public shipyards, and private shipyards involved in the construction, maintenance, and repair of ships. A Navy/lndustry Task Group lead by the Naval Sea Systems Command prepared this report of the technical and economic impact of these new and anticipated reductions in worker exposure Iimits. This report:

- Identifies the manufacturing and repair operations, materials, and processes that are expected to be impacted by the recent and antiapated reductions in exposure Iimits.
- Presents data on current Worker exposure levels to Ni, Mn, total Cr, and Cr(Vl).
- Identifies the technical and economic impact of the anticipated reductions in the Cr(VI) PEL on Navy facilities and public and private shipyards.
- Identifies future actions that may be required to comply with the recent and antiapated reductions in exposure limits.

This study concludes that workers in Navy facilities and public and private shipyards who perform the following operations have the potential for exposure to Ni, Mn, total Cr, and Cr(Vl): Construction, Structural Fabrication and Repair of Facilities; Metal Cleaning; Casting; Plating; Painting; Coating; Machining; Welding; Thermal Spraying; Thermal Cutting and Gouging Woodworking (of pressure treated Wood); and Services (includes transportation, motor vehicle, maintenance).

The study also concludes that the anticipated OSHA reduction in the Permissible exposure limit **(PEL)** for Cr(Vl) is expected to have much greater potential impact on Navy facilities and public and private shipyards than the anticipated ACGIH reduction in nickel (Ni) or the recent reduction in manganese (Mn) limits. The anticipated OSHA reduction in the Cr(VI) PEL to 0.5 µg/m³ will have the most significant technical and economic impact. While it may be practicable, it may not be economically practical to achieve a TWA exposure level of 0.5 µg/m³ for all activities. A PEL of 5 µg/m³ or 10 µg/m³ would be much more feasible.

- Exposure to Cr(VI) can be expected when the above listed operations are performed on or with materials that contain chromium or chromates. This includes chromate paints, coatings, and chromium plating. This also includes thermal processing of stainless steels, high-chromium nickel alloys (eg Alloys 600 and 625), and HY80 and HY100 low-alloy steels. HY steels and welding consumables, in particular, are widely used in Navy structures and weapon systems and have very low chromium content.

  Work on materials and with processes that contain or generate Cr(Vl) is performed throughout Navy facilities and public and private shipyards.

  Replacement of the processes and materials that contain or generate Cr(Vl) may not be possible in the foreseeable future. These materials and processes have been selected based on their performance in Navy systems. Substitutes with equal or better performance may not be available, or will require long Periods of development and analysis.

  Table 1.0 shows that the potential for exposure of workers to Cr(Vl) in excess of 0.5 µg/m³ will be significantly higher for the operations performed in Navy facilities and public and private shipyards than for higher anticipated **PEL's.**

- Exposure of workers in enclosed and confined work areas will cause particular problems for Navy facilities, shipyards, and the shipbuilding industry.

- Regulated areas for Cr(Vl) will have to be created in much greater numbers than have been required for cadmium or lead exposure. For example, in the early stages of submarine construction, the entire vessel is likely to become a regulated area for Cr(Vl).

- Local exhaust ventilation, which is the presently available engineering control, is not completely effective in reducing welder exposure to Cr(VI) below 0.5 µg/m³ for many shipyard operations or even below 5 µg/m³ in some cases.

- The inability of engineering controls, like local exhaust ventilation, to consistently reduce worker exposure below the anticipated Cr(Vl) PEL levels WiII significantly increase the use of respirators.

- The Task Group estimates that if the Cr(VI) PEL is decreased to 0.5 µg/m³, approximately 18,000 workers will be affected. This estimate represents 17 Navy facilities, 5 private shipbuilders (Navy contractors) and 6 small marine businesses. One-third of these workers are likely to be exposed to welding fumes.

- The Task Group estimates that significantly fewer workers (3,200) are likely to be affected if the Cr(VI) PEL is established at 5 µg/m³. This number is estimated to be approximately 800 workers if the PEL is set at a value of 10 µg/m³.

- The costs to the Navy and the shipbuilding industry, of reducing the Cr(Vl) PEL, will include costs for training, exposure monitoring, medical surveillance, engineering controls, personal protective equipment, regulated areas, hygiene facilities, housekeeping, and maintenance of equipment There also WiII be costs due to reduced efficiency of not only the operations involving Cr(Vl), but adjacent operations and personnel as well. One private shipyard estimates that 80% of the cost of compliance with this proposed standard WiII be lost productivity.

- The estimated costs for compliance with the anticipated OSHA Cr(Vl) standard for a PEL of 0.5 µg/m³ at Navy facilities include an initial, one-time cost of about $22,000,000 and annual costs of about $46,000,000 per year. The costs for compliance to this PEL for private shipyards are estimated to include an initial, one-time cost of about $9,000,000 and annual costs of nearly $37,000,000 per year.

- The estimated costs for compliance with the anticipated OSHA Cr(Vl) standard for a PEL of 5 µg/m³ at Navy facilities include an initial, one-time cost of about $3,000,000 and annual costs of about $5,000,000 per year. The costs for compliance to this PEL for private shipyards are estimated to include an initial, one-time cost of about $2,000,000 and annual costs of nearly $12,000,000 per year.

- The estimated costs for compliance with the anticipated OSHA Cr(VI) standard for a PEL of 10 µg/m³ at Navy facilities include an initial, one-time cost of nearly $1,000,000 and annual costs of about $2,000,000 per year. The rests for compliance to this PEL for private shipyards are estimated to indude an initial, one-time cost of nearly $2,000,000 and annual rests of about $12,000,000 per year.

- The Task Group noticed a significant difference between the anticipated OSHA PEL of 0.5 µg/m³ and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV®) for chromates. The ACGIH reconfirmed this TLV® as recently as 1994. More study by OSHA is recommended to resolve these differences.

Shipyard and laboratory worker exposure data gathered by the Task Group show that some of the operations listed above have the potential to exceed the new limits for Ni and Mn:

- Shielded metal arc welding (SMAW)j and gas metal arc welding (GMAW) of stainless steels and nickel alloys have a high potential for exposure to Ni. Shipyard worker exposure levels to Ni during GMAW of high-chromium, nickel alloys in enclosed spaces ranged from 15 $\mu g/m^3$ to over 1 mg/m^3. Over 50 percent of the samples exceeded the anticipated limit of 100 $\mu g/m^3$. Exposure levels in open spaces sampled during this study were less than 100 $\mu g/m^3$.

- Worker exposure data indicate that SMAW and GMAW of stainless steels, carbon steels, and low-alloy steels (including HY80 and HY100) have a high potential for Mn exposure.

- There may be other operations that were not sampled that have the potential for worker exposures above the new and anticipated limits for Ni and Mn.

Future work is planned by the Navy and by the shipbuilding industry in the following areas

(a) Expand worker exposure sampling to provide statistically valid characterizations of the operations, processes, and materials with potential exposure to Ni, Mn, total Cr, and Cr(VI). Further sampling is needed for

- Welding, cutting, and gouging of materials with very low chromium contents, such as mild steel and HY welding consumables.
- Operations performed in enclosed and confined spaces.cl
- Local exhaust ventilation.
- Wastes and residues, including fluxes and dusts.

(b) Expand the estimates of the technical and economic impact on the Navy and additional private shipyards.

(c) Conduct research and development to minimize hazards during fabrication and repair in Navy facilities, shipyards or other industrial work sites in the following areas

- Development of a long range exposure reduction plan.
- Evaluation of new, less hazardous base and filler materials.
- Evaluation of alternative processes with reduced emissions.
- Collaboration with Navy pollution prevention efforts related to processes.

Table 1.0 Operations Where Exposure Of WorkerS To Hexavalent Chromium May Be Anticipated At Three PEL Levels

In Open and Enclosed Work Areas Using General Ventilation (Note 1)

Operation	At PEL			At Action Level
	10 µg/m³	**5 µg/m³**	**0.5 µg/m³**	**0.25 µg/m³**
Construction, Repair, Fabrication of Navy Facilities	N	N	Y	Y
Metal Cleaning, Abrasive (Note 2)	Y	Y	Y	Y
Metal Cleaning, Chemical	N	N	Y	Y
Electroplating	N	Y	Y	Y
Painting	Y	Y	Y	Y
Coating	N	N	Y	Y
Thermal Spraying, Thermal Cutting and Gouging	N	N	Y	Y
Services (Transportation, Motor Vehicle, Maintenance)	N	N	Y	Y
Welding:				
SMAW (Ni/SS) (Note 3)	Y	Y	Y	Y
SMAW (HY80/100) (Note 4)		N	Y	
GMAW (Ni/SS) (Note 3)	N		Y	Y
GMAW (HY80/100) (Note 4)	N	N	N	
GTAW (Ni/SS) (Note 3)	N	N	N	Y

KEY: Y = Process is expected to exceed this level
N = Process is not expected to exceed this level

NOTES

1) General ventilation dilutes the concentration of the hazardous substance in the work area by natural or mechanical air movements.
2) Cr (VI) exposure during metal cleaning is primarily removal of coatings containing chromates.
3) (Ni/SS) covers welding with High-Chromium Nickel Alloys (ie Alloys 600/625) or Stainless Steels.
4) (HY80/100) covers welding with E1OO or ER1OO through E120 or ER120 consumables.

2.0 INTRODUCTION

Some of the operations Performed in Navy facilities and in public and private shipyards during the construction, maintenance and repair of ships generate airborne emissions that are potential health hazards to workers. The nature of the health hazard that may be present depends on the materials or chemicals that comprise the airborne emissions. Airbome emissions include vapors, mists, gases, dust, and fume that may be generated by or during these operations. The operations in Navy facilities and in public and private shipyards that may be involved include:

- Construction, Structural Fabrication and Repair of Facilities
- Metal Cleaning (abrasive blasting, grinding, chipping and acid cleaning)
- casting
- Plating
- Painting and Coating
- Machining
- Welding, Brazing, and Soldering
- Thermal and Non-thermal Cutting
- Services (Transportation, maintenance)
- Woodworking (of pressure treated Wood)
- Thermal Spraying

The Occupational Safety and Health Administration of the U.S. Department of Labor (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) set limits on worker exposure to potentially hazardous materials. OSHA requires that worker exposure to hazardous materials be less than the Permissible exposure limits (PEL) contained in the appropriate standard. The ACGIH publishes Threshold Limit Values (TLV®) as guidelines for worker exposure to hazardous airborne substances. (*NOTE: Threshold Limit Value and TLV® are copyrighted by ACGIH)* OSHA health and safety standards that apply to Navy workers and industrial shipyards, include Title 29 of the Code of Federal Regulations (CFR), "Part 1910 General Industry and Part 1915 Shipyard Employment'! Air contaminant levels for specific substances that may be found in shipyard operations, are covered under 29 CFR Part 1915, Subpart Z

There have been several recent announcements of actual and proposed reductions in worker exposure Iimits for airbome emissions that may have an impact on the operations and processes used by Navy facilities and public and private shipyards.

- OSHA has announced their intention to reduce the PEL for hexavalent chromium (Cr(VI)) from the present ceiling level of 100 μg/m^3, as chromates, to an 8-hour time-weighted-average (TWA) of between 0.5 μg/m^3 and 5.0 μg/m^3. A draft of the new standard is expected to be released early in 1996. The final standard is expected to be completed in 1998, with full implementation in 2000.

- In May, 1995, ACGIH reduced the Threshold Limit Value (TLV®) for manganese (Mn) fume from 1000 μg/m^3 to 200 μg/m^3.

- ACGIH has announced plans to reduce the TLV® for nickel (Ni) compounds from the present value of 1000 μg/m^3 to 100 μg/m^3 for insoluble Ni compounds and to 50 μg/m^3 for soluble Ni compounds. The final decision on this change is expected in 1997.

While OSHA has no immediate plans for reducing the PEL for nickel and manganese, many organizations control worker exposure to the lowest published accepted standard, and will likely use ACGIH. Table 20 lists the current and anticipated OSHA and ACGIH limits for Ni, Mn, and Cr Compounds.

In 1989, the Occupational Safety and Health Administration (OSHA) revised the permissible Exposure Limits (PEL's). Many of the PEL's had not been updated since the promulgation of the OSH Act of 1970. These revised PEL's were challenged in mutt and resulted in a decision by the 11th Circuit Court of Appeals to vacate the final rule of the Air Contaminants Standards. Therefore, OSHA cannot ate employers by using the 1989 revised PEL's but must rely on the original Iimits promulgated with the OSH Act of 1970. Based on the intent to maintain an effective and comprehensive occupational safety and health program promulgated under the OSH Act of 1970, the Navy continues to use the 1989 Iimits as they are more protective. This includes the STEL for manganese listed in Table 2.0. Other non-Navy employers are not obligated by regulation to use the 1989 PEL's.

The Navy and the National Shipbuilding Research Program Welding Panel (SP-7) are concerned that these recent and anticipated future reductions in worker exposure Iimits can have major impacts on the operations used for construction, maintenance, and repair of ships. A Navy/Industry Task Group lead by the Naval Sea Systems Command is addressing these concerns. The Task Group includes Navy, Army, Air Force, and industry representatives from the organizations listed in the acknowledgement section of this report. The Navy/Industry Task Group's primary focus is on those operations, materials, and processes, used in the manufacture, maintenance, and repair of Navy weapon systems and their platforms, that are expected to have the potential for worker exposure to Ni, Mn, Cr, and Cr(VI). Special attention is centered on welding, cutting, and grinding of chromium bearing materials since these operations were identified as having, perhaps, the most potential for an economic and technical impact on the Navy. The necessity to work in enclosed and confined areas is another special concern for Navy facilities, public shipyards, and the shipbuilding industry.

This report presents the results of the Navy/Industry Task Group study of the technical and economic impact of the recent and anticipated reductions in worker exposure limits. This report

- Identifies the manufacturing and repair operations, materials, and processes that are expected to be impacted by the recent and anticipated reductions in exposure Iimits.
- Presents data on current worker exposure levels to Ni, Mn, total Cr, and Cr(Vl).
- Identifies the technical and economic impact of the anticipated reductions in the PEL for Cr(Vl) on Navy facilities and shipyards.
- Identifies future actions that may be required to comply with the recent and anticipated reductions in exposure limits.

The report is organized as follows

- Section 3 provides background information that formed the basis for the Task Group study, including:

  - The expected provisions of the anticipated OSHA worker exposure standard for Cr(Vl).
  - Lists of operations, processes, materials, and consumables where worker exposure to Ni, Mn, total Cr, and Cr(Vl) is expected.
  - Sources of Ni, Mn, Cr, and Cr(VI) airborne emissions.
  - Ni, Mn, and Cr(Vl) exposure standards in other countries.

Table 2.0 Comparison of Current and Anticipated Worker Exposure_ Limits for OSHA and ACGIH

Material	Current OSHA PEL (μg/m^3)	Current ACGIH TLV® (μg/m^3)	Anticipated Change
Chromium Metal	1000 TWA (as Cr)	500 TWA (as Cr)	None
Chromium (ll&lll) compounds	500 TWA (as Cr)	Same as Cr	None
Chromates (Cr VI)	100 Ceiling (as chromates)	See individual compound	0.5-5.0 TWA (as Cr M))
Soluble Chromium (VI)		50 TWA(as Cr)	None
Insoluble Chromium (VI)		IO TWA(as Cr)	None
Lead Chromate		12 TWA (as Cr)	None
Strontium Chromate		0.5 TWA (as Cr)	None
Zinc Chromate		10TWA(as Cr)	None
Insoluble Nickel		*1000* TWA (as Ni)	100 TWA (all forms)
Nickel Metal	1000 TWA (as Ni)	1000 TWA	500 TWA all forms
Soluble Nickel	100 TWA(as Ni)	I00 TWA (as Ni)	50 TWA (all forms)
Manganese (Dust and compounds)	5000 (Ceiling) (as Mn)	200 TWA (as Mn)	None
Manganese Fume	3000 STEL (as Mn)	200 TWA (as Mn)	None

PEL - Permissible exposure limit.
TLV® - Threshold limit value.
TWA - Time-weighted-average. Average concentration time-weighted over an 8-hour workday.
ceiling - A concentration that shall (for PELs) or should (for TLV®s) not be exceeded during any part of the working exposure.
STEL - Short term exposure limit Recommended for materials that have acute effects but the toxic effects are primarily chronic (limits short term exposures even if the TWA is low). This 1989 OSHA STEL is used by the Navy.

Section 4 presents worker exposure data from:

Published literature.
The Navy Environmental Health Center's Industrial Hygiene Data Capture database.
Worker exposure samples gathered in three shipyards.
Controlled laboratory welding tests to evaluate the effectiveness of local exhaust ventilation to reduce worker exposure.

The available methods for control of worker exposure to these airborne emissions are discussed in Section 5.

Section 6 and Section 7 focus on the technical and economic issues involved in the anticipated PEL's for Cr(Vl) since the data show that Cr(Vl) WiIl have the largest affect on the facilities and operations studied.

Section 6 addresses the limitations of present technology to achieve the anticipated PEL's for Cr(Vl) and the impact of these Iimitations on operations in Navy and contractor facilities.

The economic impact of the anticipated reduction in the Cr(Vl) PEL is presented in Section 7.

The Task Group attempted to develop a position that is unbiased with regard to commercial and industry concerns, and that focuses strictly on the impact to the Navy and the shipbuilding industry. Information was gathered from many sources. The Navy and the Navy Joining Center are not responsible for the accuracy of data provided by others. It is anticipated that the Task Group wilI continue to gather information on worker exposure and to study the impact of the anticipated changes. In the future the Task Group intends to

- Develop long range exposure reduction plans to meet the new exposure Iimits.
- Evaluate cost effective techniques to reset the new Iimits.
- Evaluate alternative new engineering controls and fabrication techniques.
- Define the technical and economic impact of the recent and anticipated changes to the Ni and Mn limits.

3.0 BACKGROUND

Initial evaluations by the Task Group indicated that the impact of the anticipated OSHA hexavalent chromium (Cr(Vl)) standard will be particularly significant for the Navy and the shipbuilding industry, due to the widespread use of materials and processes that involve or produce Cr(Vl). This preliminary analysis also indicated that welding, cutting, grinding, and gouging operations would be among those most affected by the anticipated change in nickel (Ni), manganese (Mn), total chromium (Cr), and Cr-(vI) worker exposure limits. Therefore, particular attention was paid to these operations during the study. Most of the shipyard worker exposure data involved these processes. Data presented in Section 4 and Section 5 support this initial evaluation. Therefore, much of the detailed analyses of technical and economic impacts, described in Section 6 and Section 7, focused on the anticipated Cr(Vl) standard.

The following factors account for the greater impact of the anticipated OSHA Cr(Vl) standard compared to the exposure limits for nickel (Ni), manganese (Mn), and total chromium (Cr):

- The greater technical difficulty of meeting the very low anticipated PEL's for Cr(Vi).
- The more extensive expected provisions of the anticipated Cr(VI) standard, which are described in Section 3.1.
- The widespread use of materials and processes that involve or produce Cr(Vl) is much greater than cadmium. Cadmium is another material with a very low OSHA PEL. The use of cadmium is very limited while chromium is contained in many of the materials and operations used in the facilities discussed in this report. Replacerment of materials and processes that may involve Cr(Vl) is difficult because many are required to meet stringent Navy requirements.
- The number of workers perfoming operations involving Cr(Vl) is much higher than those working with cadmium. One industrial shipyard has stated that they have 72 personnel under medical surveillance for cadmium and lead. This shipyard projects 1000 welders and 1000 grinders would be impacted if the Cr(Vl) PEL is reduced to 0.5 $\mu g/m^3$. In addition, there may be an equally large number of others that work near welding, cutting, grinding, and gouging operations and are likely to be affected.
- Because of their widespread use, work on chromiurn-bearing materials is performed throughout Navy facilities, and public and private shipyards. This will require establishing regulated areas throughout the facility. For example in the case of early stages of submarine construction, the entire vessel is likely to become a regulated area for Cr(VI).

3.1 Expected Provisions of the Anticipated OSHA Hexavalent Chromium standard

This section provides background information on the provisions that OSHA has indicated will probably be part of the new worker exposure standard for hexavalent chromium (Cr(Vl)). This information guided the Task Group's study, forming the basis for evaluation of materials and operations, worker exposure measurements, and technical and economic impact analysis. OSHA has announced the new standard wiIl significantly reduce the permissible worker exposure limit for Cr(Vl) from the present ceiling level of 100 **$\mu g/m^3$** (as chromates) to an 8-hour time-weighted-average (TWA) Permissible Exposure Limit (PEL) of between 0.5 µg/m^3 and 5.0 µg/m^3. OSHA's risk assessment[1] states the new PEL should be established at the lowest practicable value. OSHA's anticipated standard for worker exposure to Cr(VI) is expected to be released to the public early in 1996. The final standard is expected to be complete in *1998, with full* implementation in 2000.

0SHA has stated the provisions in the new standard for Cr(Vl) exposure will be similar to other recent OSHA comprehensive standards (e.g. OSHA cadmium standard, 29 CFR 1915.102729, and CFR 1910.1027). Therefore, the new standard is likely to require the following:

- Exposure Limits: PEL of between 0.5 and 5.0 µg/m^3 with an action level one-half the PEL
- Exposure Monitoring Periodic monitoring of both individuals and areas.
- Medical Surveillance: Pre-placement and annual monitoring, blood and urine tests.
- Regulated Areas Where exposure to Cr(Vl) is anticipated.
- Written Compliance Program: Including the analysis of exposures, sources of exposures, and steps taken to reduce them,
- Engineering and Work Practice Controls State-of-the-art exhaust systems, and other controls.
- Personal Protective Equipment: For workers exposed to Cr(VI).
- Respirators: Respirator training with detailed fit testing and medical evaluations and respirators provided to individuals exposed at or above the PEL or upon request by the employee.
- Hygiene Facilities: Specific requirements on showering and changing clothes at the end of work shifts, and special requirements for lunch and break rooms.
- Housekeeping Practices: Work areas must be kept dean and surface contaminations eliminated.
- Training: Initial and annual worker training and documentation of training will be required with special emphasis on the hazards associated with exposure to Cr(Vl).

3.2 Facilities, Occupations and Operations Impacted By the Recent and Anticipated Exposure Limits

The focus of the Navy/Industry Task Group is on the Navy facilities and public and private shipyards that are expected to have the potential for worker exposure to Ni, Mn, Cr, and Cr(VI). Table 3.1 lists the Navy facilities and public and private shipyards that provided information for this study. This table is representative, rather than all inclusive. These organizations are assumed to be representative of Navy work sites and the shipbuilding industry.

The Task Group made an initial assessment of the occupations and operations performed in Navy facilities and in public and private shipyards who construct or repair ships. The intent was to identify those occupations and operations that would be expected to be impacted by the new worker exposure limits. The occupations and operations with potential for worker exposure to Ni, Mn, Cr, and Cr(Vl) were identified from published literature, from the Navy Environmental Health Center's industrial hygiene database (described in Section 4.2), and from industrial hygienists at industrial shipbuilders. The following occupations and operations were identified as being those where potential exposure to Ni, Mn, Cr, and Cr(Vl) would be expected to occur:

1 Evaluation of Epidemiological Data and Risk Assessment For Hexavalent Chromium, Prepared for OSHA by KS. Crump Division of ICF Kaiser under Contract No. J-9-F-1-0066, Modification No. 1, May 1995.

- Construction, Structural Fabrication and Repair of Facilities
- Metal Cleaning (includes abrasive blasting, grinding, chipping, and acid cleaning)
- casting
- Plating
- Machining
- Painting and Coating
- Welding, Brazing, and Soldering
- Thermal and Non-thermal Cutting
- Services (transportation, motor vehicle, maintenance, graphic arts, photography)
- Woodworking (of pressure treated wood)
- Thermal Spraying

Details and further assessments of these occupations and operations are discussed in Sections 4 and 5 of this report.

Table 3.1 Major Navy Facilities and Shipyards Participating in This Study

Facility	Types of Activities
Norfolk Naval Shipyard, Norfolk VA	Repair and upgrade of Naval ships
Puget Sound Naval Shipyard, Bremerton, WA	"
Long Beach Naval Shipyard, Long Beach, CA	"
Pearl Harbor Naval Shipyard, Pearl Harbor, HI	"
Portsmouth Naval Shipyard, Portsmouth, NH	"
Philadelphia Naval Shipyard, Philadelphia, PA	Foundry operation
Charleston Naval Shipyard, Charieston,SC	Repair and upgrade of Naval ships
Navy Surface and Air Warfare Centers and Aviation Depots	
Navy Aviation Depots: at North Island (San Diego CA), Cherry Point (Cherry Point NC), Jacksonville (Jacksonville FL)	Repair of Aircraft
Navy Surface Warfare Centers	Material and machinery studies
Navy Air Warfare Centers	Material and machinery studies
Naval Underwater Warfare Center	
Shore Intermediate Activities	Ship repair
Intermediate Maintenance Activities	Ship repair
Surface Fleet, Atlantic	Ship repair
Private shipyards	
Bath iron Works, Bath ME	Construction of surface ships such as
Ingalls Shipbuilding, Pascagoula, MS	DDG-51 class destroyers and cruisers
General Dynamics, Electric Boat Division, Groton,CT	Construction and repair of submarines
NASSCO, San Diego, CA	Construction of surface ships such as AOE class
Newport News Shipbuilding, Newport News, VA	Construction of aircraft carriers, submarines and repair of surface ships, commercial ships
Avondale Shipyards, Inc. New Orleans, LA	Ship manufacture and repair
Trinity Marine Group, New Orleans, LA	Ship manufacture and repair
Sigma Welders & Fabricators, Houma, LA	Ship manufacture and repair
Bollinger Welders & Repair, Lockport, LA	Ship manufacture and repair
Houma Fabricators Inc., Houma, LA	Ship manufacture and repair
Quality Shipyards, Inc., Houma LA	Ship manufacture and repair

NOTE: This table is representative, rather than all inclusive, Worker exposure depends on occupations, operations, process, materials, the nature of the work area, (whether open, enclosed, or confined) ventilation, and the time of exposure. The necessity to work in enclosed and confined areas is a special concern for Navy ships, facilities, shipyards, and the shipbuilding industry. The Task Group used the following definitions of work spaces:

Confined Space: A compartment or area configured to provide limited or restricted access and not intended for continual employee occupancy such as a double bottom tank cofferdam, boiler, tunnel, silo, bin, hopper, or other space. The small size and confined nature can readily create or aggravate a hazardous exposure.

Enclosed Space: (1) Ships or modules: Any space other than a confined space, which is enclosed by bulkheads and overhead. (2) Shops Spaces of less than 10,000 cubic feet per worker or having a ceiling height of less than 16 feet

Open Space: (1) Ships or modules: Any space having one or more bulkhead or overhead open. (2) Shops: Spaces greater than 10,000 cubic feet per worker or having a ceiling height of 16 feet or greater.

3.3 Sources of Airborne Emissions

3.3.1 Materials Where Nickel, Manganese, Chromium, and Hexavalent Chromium May Be Encountered

Worker exposure to Ni, Mn, Cr, and Cr(VI) during metal cleaning, grinding, and machining operations occurs when these operations are performed on materials that contain Ni, Mn or Cr, or materials that are painted, coated, or plated with these materials. Ni and Cr are found in stainless steels, nickel alloys (including nickel-chromium alloys and copper-nickel alloys), and carbon and low-alloy steels (including HY80 and HY100 steels.) Manganese is a minor alloying element in all of these materials. Removal of chromate paints during manufacture or repair of ships can produce Cr(Vl). Painting operations using chromate paints and electroplating of chromium are additional sources of Cr(Vl). Welding, casting, thermal cutting, and thermal spraying processes produce fumes that may contain Ni, Mn, Cr and Cr(Vl) if these oprations involve base or filler metals that contain Ni, Mn, or Cr. The next section of the report discusses the sources of arc welding fumes in greater detail. Table 3.2 lists base metals and welding filler materials that are commonly used in the facilities and operations discussed in this report that contain chromium and nickel. All steels, and the materials listed in Table 3.2 contain manganese.

3.3.2 Sources of Arc Welding Fume

The American Welding society (AWS) defines six arc welding processes that are widely used for fabrication, repair and maintenance of ships:[2]

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)
- Flux Cored Arc Welding (FCAW)
- Gas Tungsten Arc Welding (GTAW)

[2] ANSI/AWS A3.089. Standard Welding Terms and Definitions Miami,Florida: American Welding Society, 1989.

- Submerged Arc Welding (SAW)
  Plasma Arc Welding (PAW)

The most widely accepted fume formation mechanism for welding processes is described by Heile and Hi11[3] as vaporization, oxidation and condensation. Heat from the welding arc vaporizes elements in the filler metal, fluxes and, to a lesser extent the base metal. These vapors are oxidized by air surrounding the arc and by oxygen that may be present in the arc atmosphere. The vaporization /oxidation mechanism is consistent with test data that show electrodes, filler wires and electrode coatings are the main sources of welding fumes Vaporization of the base metal is responsible for less than 10 percent of total welding fume[4]. However, volatile coatings, such as paint, plastic, primer, rust, oil, or zinc, on the surface of the base metal can cause significant increases in the amount of fume generated.

3.3.2.1 Rate of Fume Generation

The quantity of fume generated during welding depends on the welding process, welding parameters, and consumab!es[4]. increased welding current and voltage will increase fume due to increased arc temperature. Elements with low vapor pressures will vaporize more rapidly than those with high vapor pressures. Gas shielded processes (GTAW, PAW, GMAW) produce less fume than open-arc processes such as SMAW and self-shielded FCAW. Shielding gases with high oxygen potentials, such as $C0_2$ produce more fume than argon-based shielding gases. Arc stability also influences fume generation because unstable arcs tend to entrain more air into the arc atmosphere, and therefore generate more fumes.

The rate of fumes generated by GTAW and PAW are very low[4]. Fumes primarily come from vaporization of the molten weld pool which is relatively small. Since the arc and molten weld pool are covered by a granular flux during submerged arc welding, fume generation rates are very low. Fume generation rates for **GMAW** are higher than **GTAW** but lower than SMAW or FCAW. The primary source of GMAW fume is vaporization and oxidation of filler metal as molten droplets are transferred through the arc. Short circuiting transfer and droplet spray transfer generate low fume levels while globular transfer and spray transfer at high welding currents and high arc voltages generate the highest fume levels. SMAW and FCAW processes generate more fumes than other arc welding processes because of the highly volatile ingredients in electrode matings and fluxes.

3.3.2.2 Cmpositions Of Welding Fume

On`-site measurements of fume concentration are required to determine actual worker exposure for a given application and this cannot be easily generalized or applied to other situations. Worker exposure is discussed in Section 4. Worker exposure levels depend not only on the generation of fumes by the welding process, but on the position of the welder in relation to the arc, and on local ventilation in the area. However, the composition of welding fumes can be estimated from the

[3] Heile, R.F. and Hill, D.C. Particulate Fume Generation in Arc Welding Processes. Welding Research Supplement to the Welding Journal, July, p. 201s-210s. American Welding Society, 1975.

[4] American Welding Society. Fumes and Gases In The Welding Environment. Miami, Florida: American Welding Society, 1979.

Table 3.2 Chromium and Nickel Containing
Base and filler metals

Group	%Cr	%Ni	Description
			Base Metal Groups
S-3	0.25-0.45	.5max	Carbon molybdenum steels, G-Mo
S-4	0.75-0.95	.5-3	Alloy steels (Cr content 3/4-2 percent, total alloy content 2-3/4 percent), Cr-Mo
S-5	0.9-1.5	.5-3	Alloy steels (total alloy content 10 percent max), Cr-Mo
	11.5-14	2-3	High alloy steels (martensitic), 410
S-8	16-min.	5-16	High alloy steels (austenitic), 304,309,310,316
S-11A	1-1.8	1-3.5	Quenched and tempered alloy steels, HY-80/100
S-11B	0.4-0.7	3-4	Quenched and tempered alloy steels, HY-130
S-11C	0.6-0.9	.7-1.5	Age hardening alloy steel, HSLA-80
S-11D	0.45-0.75	.7-1.5	Age hardening alloy steel, HSLA-100
s-34		10-30	Copper Nickel (CuNi 70/30, 90/10)
		93	Nickel
S-42	-	70	Nickel-Copper (Monel)
S-43	14-23	60-70	Nickel-chromium iron, Inconel 625
255	24-27	4-5.5	Ferralium 255
			Filler Metal Groups
A-2A	0.15 max	.4 max	Carbon and low alloy steel (covered electrode), 7018
A-2D	0.20 max		Low alloy steel (flux cored electrode), 70T-1, 71T-1
A-3A	0.15 max	.8-3.75	Carbon and low alloy steel (low-hydrogen covered electrode), 8018-C3, 8018-C1, C2
A-5A	0.40-1.50	1.25-3.8	Low alloy, high-yield steel (covered electrode), 1018-M1, 11018-M, 12018-M2
A-5B	0.8 max		Low alloy, high-yield steel (bare electrode), 100S-1, 120S-1, 140S1
A-6A	1-2.5		Cr-Mo steel (1.0 to 2.50 percent Cr, 0.4 to 1.2 percent Mo) (covered electrode), 8018-B2L
A-7A2	4-13.5	.3 max	Cr-Mo steel (4.0-13.5 percent Cr, 0.4-1.4 percent Mo) (covered electrode), 41015,410-16
A-7B2	5-6	.3 max	Cr-Mo steel (5-6 percent Cr, 0.4-1.4 percent Mo) (bare electrode)
M-8A	14-32	.3 max	High alloy steel (austenitic) (covered electrode), 308,309,310, 316
A-8B	18-32	.3 max	High alloy steel (austenitic) bare electrode, rod and insert), 308,309,310,316
A-34	-	10-30	Copper Nickel (CuNi 70/30, 90/10)
A-41	-		Nickel (EN61)
A-42		70	Nickel-Copper (Monel EN60)
A43A	13-23	58-70	Nickel base alloys (covered electrode), IN12, 8N12
A-43B	14-23	58-70	Nickel base alloys (bare electrode), EN62, 82,625

Notes:
Group MIL-STD248D designations
%Cr: General Cr content
%Ni: General Ni content
Description: MIL-STD248D description plus a typical material type from the group

composition of the electrode or filler wire[4]. This estimation is relatively straight forward for GMAW, but is more complex for processes that involve fluxes such as SMAW, FCAWand SAW. Coatings on revered electrodes and core materials in flux cored wires include silicates, carbonates, fluorides, and oxides of potassium, calcium, magnesium, sodium, titanium and aluminum. Welding electrode manufacturers provide material safety data sheets (MSDS) that identify the approximate percentages of hazardous materials.

Table 3.2 lists welding consumables that are expected to produce fumes containing nickel and chromium. Table 3.3.1 and Table 3.3.2 show typical fume compositions of a number of the common welding consumables used in shipyards. The total weight of elements in the fume reported in these tables does not equal 100 percent because only the major constituents in the fume were analyzed, and approximately one-third on the fume is oxygen. These tables show that the primary components in mild steel welding fume are oxides of iron, manganese and silicon. Some Iow-alloy steel electrodes contain nickel and chromium so Ni, Cr and Cr(Vl) can be expected in the welding fume. The primary concerns for Cr(Vl) fumes are from welding stainless steels, high-chromium nickel alloys, and hard surfacing electrodes. SMAW and FCAW using electrodes of stainless steel or high-chromium, nickel-alloys have been shown to produce fumes with significant percentages of Cr(Vl). Concern is greatest with these processes compared to GMAW, PAW, and GTAW fumes from these alloys which contain very Iittle Cr(VI). The production of Cr(Vl) during SMAW or FCAW increases when sodium and potassium are present in the electrode coatings or fluxes[5]. Reducing the amount of these elements in electrodes and fluxes will reduce the production of Cr(Vl) in the fume. Moreton[6] reports that the Cr(VI) in stainless steel SMAW Welding fume is at least 90% water soluble (soluble in water or in weak caustic solutions.) Kimura[7] reports stainless steel GMAW fume contains very Iittle Cr(Vl) which may include troth soluble and insoluble portions. Nickel alloys and stainless steels also produce Ni and Mn fumes. Manganese also is a constituent of welding fume from carbon steels and Iow-alloy steels.

[5] Carter, G, Stainless Steel MMA Wedling - Fume Safety Under The Spotlight, TW Research Bulletin, Jan./Feb, 1992, pg 14-18.

[6] Moreton, J., Bettelley, J., Mathers, H., Nicholls, A, Perry, RW., Ratcliffe, D. B., Svensson, L, Investigation of Techniques for the Analysis of Hexavalent Chromium, Total Chromium and Total Nickel in Welding Fume: A Co-Operative Study, Ann. Occup. Hyg., 1983, Vol. 27, No. 2, pp. 137-156.

[7] Kimura, M., Kobayashi, M., Godai,T., Minato, S., 1979, Investigations on chromium in Stainless Steel Welding fumes, Welding Journal Research supplement July 1979, pp 195s-204s.

Table 3.3.1 Approximate Weight Percentages of Major Constituents in Arc Welding Fume
(It is assumed that the constituents are present as oxides)

Element	SMAW				GMAW
	E-7018(1)	E8018C3 (2)	E9018B3(2)	E9018B3(3)	ER70S-3(2)
Iron	29.5	45.2	21.9	11.6	55.4-63.7
Manganese	6.4	7.2	5.9	3.9	3.4-8.5
Silicon	4.7			4.5	0.5-2.5
Chromium	–	0.1	1.6	0.5 (CRIII) 0.6 (CRVI)	-
Nickel	–	0.3	0.1	0.02	-
Fluorine	3.4	35.8	28.1	18.7	-
Potassium	9.9			16.3	-
Calcium				9.5	–
Sodium	2.9			1.9	-
Copper					-
Aluminum				2.2	0.1-1.8
Magnesium					
Molybdenum		<0.1	<0.1	0.1	

Sources:
(1) McLiwain & Neumeier, Fumes From Shielded Metal Arc Welding Electrodes U.S. Dept. Of Interior, Bureau of Mines, Report 9105.
(2) American Welding Society, Fumes and Gases In The Welding Environment. Miami, Florida: American Welding Society, 1979.
(3) Tandon, Crisp, Ellis, Baker, Investigation of Electric Arc Welding Fumes, Australian Welding Research, December 1984, pg 55-59.

Table 3.3.2 Approximate Weight Percentages of Major Constituents in Arc Welding Fume
(It is assumed that the constituents are present as oxides)

Element	SMAW		GMAW			
	E316L(1)	E316L(2)	ERNiCrMo-3 (1)	ER316LSi(1)	ER312(1)	ER410(1)
Iron	9.2-11.7	6.5	6.4-13.3	26.4-35.0	24.3-30.2	53.2
Manganese	3.8-5.2	3.3	0.9-1.6	8.3-21.2	10.6-17.9	3.9
Silicon	2.6-7.5	–	<0.1	1.3-3.3	0.3-1.0	1.2
Chromium (III)	4.3-6.5	5.1	14.0-15.9	9.82-13.2	22.3-27.0	9.2
Chrome (VI)	3.3-3.7	–	0.2-0.5	0.2-0.4	0.3-0.9	0.2
Nickel	0.9-1.2	0.7	32.3-35.5	3.1-6.1	2.0-3.9	0.2
Fluorine	13.3-23.1		–	-	–	–
Potassium	16.6-18.6		–	-	–	–
Calcium	0.6-10.7		–	-	–	–
Sodium	-		–	–	–	–
Copper	–		–	0.1-0.3	0.1	–
Aluminum	0.6-1.3		–	-0.1-0.6	0.1	–
Magnesium	–		–	0.1-0.8	–	–
Molybdenum	<0.1		2.9-5.5-	0.1-0.6	<0.1	

Sources: (1) Moreton, Smars, Spiller, Fume Emission Welding Stainless Steel, Metal Construction, December 1985, pg 794-798.
(2) Tandon, Crisp, Ellis, Baker, Investigation of Electric Arc Welding Fumes, Australian Welding Research, December 1984, pg 55-59.

3.4 Number of Potentially Exposed Workers

Information was gathered on populations of workers who are potentially exposed to Cr(Vl) in the Navy ships and facilities and shipyards listed in Table 3.1. These same workers are also potentially exposed to nickel and manganese. The details of these worker populations are presented in Section 7 of this report, In addition to the workers discussed in Section 7, in 1994, there were 124,400 total production workers employed in the ship and boat building and repairing industry in the United States. Section 7 shows that the majority of workers potentially exposed to Cr(Vl) in public and private shipyards are directly involved in welding, cutting, grinding, and gouging operations. Another large population of shipyard workers who will potentially be exposed are shipfitters, riggers, and other outfitting trades that work near welding, cutting, grinding, and gouging operations.

This preliminary analysis indicates that welding, cutting, grinding, and gouging operations will be seriously affected by the anticipated change in Cr(Vl) worker exposure Iimits. Therefore, particular attention was paid to these operations during the Task Group study. Most of the shipyard worker exposure data in Section 4 of this report involved these processes.

3.5 Other Environmental, Health and Safety Regulations that Apply to Work Sites

Navy workers and industrial shipyards are covered by OSHA standards in Title 29 of the Code of *Federal Regulations* (CFR) including Part 1910 “General *Industry"* and Part 1915 *“Shipyard Employment".* Air contaminant levels for specific substances that maybe found in the shipyard welding operations workplace, such as lead, Cadmium, and asbestos, are covered under 29 CFR Subpart Z

Executive Order 12856 requires pollution prevention plans with annual updates as well as compliance with the Emergency Planning and Community Right-to-know Act (EPCRA). Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) requires the owners or operators of certain manufacturing facilities to submit annual reports on the amounts of listed chemicals released by their facility into the environment Shipyards submit these annual reports (Form R reports) to the U.S. Environmental Protection Agency (EPA) already. Chromium compounds are included on the list of section 313. Toxic chemicals and shipyards with chromium emissions must generally track and report on total annual releases, including those releases generated by welding operations. In order to calculate annual chromium emissions from welding operations, shipyards use the Federal AP-42 *Hazardous Air Pollutant (HAP) Emission Factors* for welding operations.

In addition to EPCRA section 313 reporting requirements, chromium compounds have been designated as a hazardous air pollutant (HAP) under provisions of Title Ill of the Clean Air Act, as amended in 1990 (CAA). HAP emissions are being regulated by EPA through the establishment of control standards for various source categories that emit one or more HAP. Major sources, those sources emitting, or having the potential to emit, 10 tons per year or more of any one HAP or 25 tons per year or more of any combination of HAP, are generally being targeted first. For certain source categories area sources (sources emitting below the major source threshold) have also been targeted. At the present time, however, the EPA has not established a specific welding source category due for regulation. Currently major sources include chromic acid anodizing and chrome electroplating.

3.6 International Worker Exposure Standards

The welding societies in 19 countries contacted to obtain information about worker exposure standards and current welding practices. Detailed responses received from five countries are discussed in this section. Information was also obtained from “Ocapational Exposure Limits - Worldwide, AlHA, 1987. Table 3.4 summarizes the PELs for Ni, Mn, total Cr and Cr(VI) in the countries for which information was available. Based on the international standards available the PEL’s for Cr(Vl) range from 20-50 $\mu g/m^3$.

Table 3.4 Worker Exposure Limits in Other Countries

Country	Hexavalent Chromium **PEL (µg/m³)**	Chromium **PEL (µg/m³)**	Nickel **PEL (µg/m³)**	Manganese **PEL (µg/m³)**
Australia	50			
Denmark	20 Soluble Cr(VI)	-		
Finland	50 Zinc Chromate, soluble Cr(Vl)			
France	50	100	1000- Insoluble Ni 100- Soluble Ni	1000
Germany (Note)	50		500	5000 Mn Compounds I000-Mn0
New Zealand	50		I000	1000
Norway	20 Chromates (certain insoluble forms), Lead Chromate			
Sweden	20 Soluble Cr(Vl) compounds	-		
U.K	50 Insoluble Cr(Vl)			

Note: The Technical Guide Concentration (TRK) for Cr(Vl) is 50 µg/m³, but for SMAW welding with revered electrodes the TRK is 100 µg/m³. The TRK is defined as "the concentration of a substance in the air at the workplace, which can be reached according to the state of technology." TRK therefore, is the lowest level to be reached when using modern technical processes and equipment

4.0 WORKER EXPOSURE DATA

This section of the report contains data on worker exposures to nickel (Ni), manganese (Mn), chromium (Cr), and hexavalent chromium (Cr(Vl)) airborne emissions. Section 4.1 presents data from published literature on worker exposure to welding fume. The Industrial Hygiene Data Capture database at the Navy Environmental Health Center was researched for worker exposure data and the results are reported in Section *4.2* While this historical data provides a perspective on worker exposure, the discussion in Section 4.2 points out a number of problems in using this historical data to estimate future exposures at the anticipated new limits. The historical data on Cr(VI) exposures are based on 15-minute ceiling samples that used the NIOSH 7600 analytical method. There are problems with the sensitivity of the NIOSH 7600 method at Cr(VI) levels as low as 0.5 µg/m³. There are also problems converting 15-minute ceiling results for Cr(VI) to 8-hour exposure values. Historical worker exposure data from shipyard databases suffers from the same problems. Therefore, the Task Group recognized the need to collect new worker exposure samples. Section 4.3 contains the results of worker exposure tests conducted by the Task Group under controlled laboratory renditions to evaluate the effectiveness of local exhaust ventilation. Section 4.4 describes the sampling plan that was devised to collect worker exposure samples in three shipyards. Samp!es included Cr(Vl) using draft OSHA Method 215 and Ni, Mn, and total Cr using NIOSH Method 7300. The results of these samples are reported in Section 4.5.

4.1 Review of Existing Welding Fume Exposure Literature

Literature on worker exposure to welding fume was examined because welding is one of the shipyard operations identified that may have high potential for exposure to Ni, Mn, Cr, and Cr(VI) airborne emissions. Literature on the composition of welding fume is discussed in Section 3.3.2. This information can be used to estimate worker exposure to Ni, Mn, Cr, and Cr(VI) in welding fume basal on the level of total fume exposure. In addition, literature searches identified a number of papers that contain data on actual welder exposures to fume. The following paragraphs summarize the findings of this review of literature.

Table 4.1.1 shows estimated maximum potential welder breathing zone exposures to Ni, Mn, Cr(lll) and Cr(Vl) for welding operations where total fume expusures range from 10-3000 µg/m³. These estimates were made by multiplying the reported percentages of individual metals (Ni, Mn, Cr(lll), and Cr(Vl)) in the fume by the total potential fums exposure. The percentages of individual metals in welding fume are discussed in Section 3.3.2.2 of this report. The upper range of total fume exposures used in Table 4.1.1 are consistent with the average total fume exposure reported in the studies discussed below (see table 4.1.3). The lower end of the range of total fume exposures used in Table 4.1.1 was chosen to reduce Cr(Vl) exposure to less than 0.5 µg/m³. These estimates suggest that reducing exposure to Cr(Vl) below 0.5 µg/m³ for SMAW of stainless steel would require lowering total fume exposure for the welder to 10 µg/m³. It should be pointed out that studies by **AWS and** by Ulfvarson, which are cited below, show that even under the best renditions, local exhaust ventilation may not be effective in reducing total fume exposure to the necessary levels to control exposure to the anticipated limits[1,2]. These estimates also indicate that Ni and Mn exposures may exceed the new and anticipated limits for gas metal arc welding (GMAW) of stainless steel and chromiurnnickel alloys when total fume exposure exceeds about 1000 µg/m³. SMAW and GMAW of carbon steel and low alloy steels may produce fumes that exceed the new Mn limit when total fume exposure reaches about 3000 µg/m³.

---

[1] Ulfvarson, U., 1986. Air Contaminants Involved in Welding In Swedish Industry - Sources of Variation in Concentrations, Proceedings of the Intemational Conference on Health Hazards and Biological Effects of Welding Fumes and Gases, Copenhagen. 18-21 February, published by Excerpta Medica, New York pg 133-136.

An American Welding Society study, published in 1982 is directly applicable to the issue of worker exposure to Ni, Mn, total Cr, and Cr(Vl) in welding fumes[2]. This study was undertaken to determine the technical feasibility of reducing welder exposure to stainless steel shielded metal arc welding (SMAW) fumes using local exhaust ventilation. Tests were performed with 5/32-inch diameter E 308-16 SMAW electrodes at 130 amperes. These tests were conducted under laboratory renditions that simulate open and confined working renditions. Results, summarized in Table 4.1.2, show that in the open space with general ventilation, only Cr(Vl) exposure exceeded the anticipated new limits. However, all elements exceeded the anticipated limits in the confined space with general ventilation. This study showed that welder breathing zone exposure to Cr(VI) was 45 µg/m^3 in an open space and 904 µg/m^3 in a confined space with general ventilation. Proper use of local exhaust ventilation reduced Cr(Vl) fume to 1.5 - 1.6 µg/m^3 in the open space and to 1.3 - 5.4 µg/m^3 in the confined space. Local exhaust ventilation reduced Ni fume to about 5 µg/m^3 in the open space and to between 7 and 11 µg/m^3 in the confined space. While this data does show significant reductions in fume using local exhaust ventilation, even under controlled laboratory renditions while using recommended practices for local exhaust ventilation, it was not possible to reduce Cr(Vl) exposure below 1.3 µg/m^3 (or total fume below 174 µg/m^3) in open or confined workspaces.

A study by Gray and Gerin[3] gathered worker exposure data on fumes from welding and cutting stainless steels in industrial companies, including shipyards. This paper presents average expected welder exposures to total fume, chromium Cr(Vl), and nickel fumes in open workspaces without local exhaust ventilation. These data are presented in Table 4.1.3. The authors estimate that use of properly positioned local exhaust ventilation will reduce exposure by a factor of 2 and welding in confined spaces wiIl increase exposure by a factor of 2. The average exposures reported by Gray and Gerin are higher than most of the welder breathing zone data recently gathered in the shipyards by this Task Group and reported in Section 4.5. However, the Gray and Gerin data maybe more representative of other industries or renditions. These data suggest welder exposure to Ni, total Cr, and Cr(Vl) may exceed the new and anticipated exposure limits for some processes and conditions.

Two papers[4,5] provide actual welder breathing zone fume measurement data taken during production welding of stainless steel. Van Der Wal's samples were collected in open shop conditions without local exhaust ventilation. Frosts and Mason's data were taken in enclosed work areas with ventilation at a rate of 4000 cubic feet per minute per welder. Frosts and Mason also took samples from workers who were grinding stainless steel as well as samples from the general work area. Data from both papers are summarized in Table 4.1.4. These data show the wide range of exposures that are possible during actual shop conditions. Van Der Wal's samples for SMAW of stainless steels revealed some very high levels of total fume, Ni, Cr, and Cr(Vl). Some of these data are similar to the AWS data in a confined space The remainder of the data generally agree with that of the other studies described above.

---

2 Welding Fume Control, A Demonstration Project, American Welding Society, Miami, FL, 1982.

3 Gray, C.N. and Gerin, M., Retrospective Estimation of Exposure to Welding Fume, International Institute of Welding (IIW) doqcument VIII-1709-94, 1994.

4 Froats, J.F and Mason, P.J., 1986. Worker Exposure to Welding Fumes and Gases During Hydraulic plant Turbine Repair, Proceedings of the International Conference on Health [illegible] Gases, Copenhagen, 18-21 February, published by Excerpta Medica, New York pg 137-140.

5 Van Der Wal, J. F., 1986. Exposure of Welders to Fumes, Cr, Ni and Cu and Gases from the Welding of Stainless and High Alloy Steels, Ibid. pg 145-148.

In summary, published literature provides limited information on actual welder exposure to Ni, Mn, total Cr, and Cr(VI). The available data indicate that arc welding of stainless **steels** and high-chromium, nickel alloys may result in welder breathing zone exposures above the new and anticipated exposure limits for Ni and Cr(VI). There is a high probability of welder breathing zone exposures exceeding the anticipated OSHA Cr(VI) PEL of between 0.5 μg/m^3 and 5.0 μg/m^3. Furthermore, the data suggest that use of local exhaust ventilation may not be completely effective in reducing Cr(VI) exposure to 0.5 μg/m^3 for SMAW of stainless steel. SMAW and GMAW of carbon steels, low alloy steels, and stainless steels also may exceed the new limits for Mn.

Table 4.1.1 Estimated Maximum 8-Hour TWA Welder Exposure (in μg/m^3) for Selected Levels of Total Fume Exposure

PROCESS/ELECTRODE	Total Fume Exposure					
Fume Component	3000	1000	500	200	20	10
SMAW - E316L						
Chromium (III)	195	65	32.5		1.3	0.65
Nickel	110	37	18.5	7.4	0.74	0.37
	36	12	6		0.24	0.12
Manganese	156	52	26	10.4	1.04	0.52
GMAW- ERNiCrMo-3						
Chromium (III)	477	159	79.5	31.8	3.18	1.59
Nickel		5				0.05
	1065	355	177.5	71.0	3.55	3.55
Manganese	48	16	8	3.2	0.32	0.16
GMAW - E316L						
Chromium (III)	396	132	66	26.4	2.64	1.32
Nicel	12	4		0.8	0.08	0.04
	183	61	30.5	12.2	1.22	0.61
Manganese	636	212	106	42.4	4.24	2.12
SMAW- E7018						
Manganese	192	64	32	128	1.28	0.64
GMAW - ER70S-3						
Manganese	255	85	42.5	17	1.7	0.85

source: Maximum percentages of elements from Table 3.3.2 used to estimate exposure based on total fume exposure.

Table 4.1.2 Welder Breathing Zone Fume Exposure
for SMAW of Stainless Steel (in µg/m^3)

Condition	Total Fume	Manganese	Total CR	CR(VI)	Nickel
Open Space - Ventilation	3,757	13.2	33	45	11
Open Space - Local Exhaust Ventilation	174-384	2.5- 7.4	2.5- 9.9	1.5- 1.6	5.0- 5.5
Confined Space - General Ventilation	33,335	651	699	904	101
Confined Space - Local Exhaust Ventilation	238-1,733	2.0-21	2.5-28	1.3- 5.4	7.0-11

Source: AWS Demonstration Project

Table 4.1.3 Average Worker Fume Exposure
for Welding and Cutting Stainless Steel (TWA in µg/m^3)

Process	Total Fume	Total CR	CR(VI)	Nickel
SMAW	3000	150	120	30
GMAW	3000	300	9	150
GTAW	1000	10	5	10
Plasma Cutting	6000	600	20	100

Source: Gray and Gerin

Table 4.1.4 Worker Breathing Zone Fume Exposure
for Welding and Grinding Stainless Steel (TWA in µg/m^3)

Process (Source)	Total Fumeq	Total CR	CR(VI)	Nickel
SMAW(1)	2000-40000	30-1600	25-1500	10-210
GMAW(1)	1500-3000	60	<1	30
GMAW (2)	670-8300	8-37	0.1 -3.4	
GTAW (1)	800-3000	10-55	<1	10-40
Grinding (2)	1500-21600	17-108	1.1- 3.1	
GMAW - Area Sample (2)	1400-2150	17-27	0.2- 0.5	

Sources: (1) Van Der Wal
(2) Frosts and Mason;

4.2 Navy Environmental Health Center Exposure Evaluation

The Industrial Hygiene Data Capture database at the Navy Environmental Health Center (NAVENVIRHLTHCEN) contains the results of air sampling collected during representative industrial operations at Navy activities. The samples have been analyzed by the Consolidated Industrial Hygiene Laboratories (CIHL'S) and entered into the database if they met the minimum industrial hygiene requirements for validity. This existing database was used to assess exposure potentials for Ni, Mn, total Cr, and Cr(Vl), in an attempt to identify

a. The processes and/or operations that have been sampled for Ni, Mn, total Cr, and Cr(Vl),

b. The current use of respiratory protection,

c. Work conditions (i.e., confined space, engineering controls, or local exhaust) that can significantly affect exposure.

The workplace assessment was based on homogeneous exposure groups of workers with similar probabilities of exposure. These exposure groups were formed using a task approach by applying operation codes of the Navy's Industrial Hygiene Field Operations Manual (IHFOM) for the specific operation performed. Table 4.2.1 lists the operations in the NAVENMRHLTHCEN database previously sampled for Ni, Mn, total Cr, and Cr(Vl). Assumptions were made in order to compare the existing database sample results to the anticipated Cr(VI) limits. Only eight-hour tirne-weighted average (8-Hour TWA) measurements greater than a sufficient volume (based on total sample time) were used. The "less than" values were taken at face value.

Data from the NAVENVIRHLTHCEN database for worker exposure to Ni and Mn are shown in Table 4.2.2 through Table 4.2.5. Data for total Cr exposure during welding are shown in Table 4.2.6. Workplace exposures may be described by a lognormal distribution[6]. Since the one sided tolerance limit applies to normal distributions, the lognormal distribution of exposures is transformed into a normal distribution by taking the logarithm of the exposure values. The data are presented as the number (N) of air samples conducted in each operation category, the geometric mean (GM), the geometric standard deviation (GSD) and the upper tolerance limit (UTL)[7,8]. The (UTLs) were computed from the sampling data with a level of confidence of 95% (gamma =0.95) that the interval they bound contains a desired proportion (p= 0.90) of the log normal distribution. This represents the 95% confidence level of the lower 90% of the defined population. Therefore, based on the number of samples taken, an exposure estimate for the target population of the workers (the workers performing the operation) is 95% confident that 90%of the TWA exposures of population performing the operation were below the UTL

The UTL estimates in Table 4.2.2 show that metal cleaning, coating, thermal cutting, and thermal spraying operations have the potential to exceed the anticipated new ACGIH limits for insoluble nickel compounds. Nickel welding fume exposures in this database, listed in Table 4.2.4 are below the anticipated new limits. None of the UTL estimates in Table 4.2.4 are above the new ACGIH limit for Mn of 200 $\mu g/m^3$. However, the estimates for metal cleaning, welding, and thermal cutting operations indicate that some of these operations could exceed this limit. In fact the data in Table 4.2.5 show that

---

[6] Rappaport, S.M. and S. Selvin: "A Method for Evaluating the Mean Exposure from a Lognorrnal Distribution." American Industrial Hygiene Association Journal. 48(4): 374-379, 1987.

[7] Hawkins, N. C., Norwood, S.K and Rock, J. C.: A Strategy for Occupational Exposure Assessment. Akron. American Industrial Hygiene Association. 1991.

[8] Leidel, N,A and KA Bush, "Statistical Design and Data Analysis Requirements." Patty's Industrial Hygiene and Toxicology Volume 3A, Second ed., edited by LJ. Cralley and LV. Cralley, New York John Wlley and Sons, Inc., 1985.

even though the average of all welding operations does not exceed 200 µg/m³, SMAW operations may exceed this level.

Previous sampling strategies for Cr(VI) supported the permissible exposure limit (PEL) as chromic acid and chromates based on an acceptable ceiling concentration per 29 CFR 1910.1000 Table As most of the sampling conducted was used to determine "compliance" with the 15 minute ceiling limit, extrapolating such exposure results to an eight-hour time-weighted average (TWA) is difficult. Therefore, historical monitoring results cannot be directly used to predict exposure to the anticipated new Cr(VI) PEL'S.

Many Navy industrial hygienists have evaluated work operations using the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs®)[9] as a workplace standard. However, the TLV® differs from one chromate compound to the next and the analytical methods cannot differentiate the chromium in strontium chromate from the chromium in zinc chromate or lead chromate. Problems with the sensitivity of the analytical method (NIOSH 7600) at the 0.5 µg/m³ strontium chromate TLV® (as chromium) forced many industrial hygienists to sample for corresponding metals (such as Sr, Zn and Pb, etc.) and perform stoichiometric conversions. Many assumptions are made concerning the stoichiometric relationship between the Sr, Zn and Pb (i.e., partitioning of the metals). As such, the stoichiometric data are not presented.

Two approaches were used to overcome these historical inadequacies of the database while estimating Cr(VI) exposure:

a. Table 4.2.7 and Table 4.2.8 present industrial hygiene sample data based on a tiered approach. Many of the samples were taken to judge compliance with the existing OSHA Cr(VI) ceiling limit. To add confidence to the evaluation of the-se exposure data as they relate to an eight-hour time-weighted average (TWA) assessment the only samples considered were those with a total sampling time of 200 minutes or greater (Table 4.2.7). This is the minimum sampling time to provide a level of detection (LOD) at, but not below, the anticipated PEL of 0.5 µg/m³ based on a general LOD of 0.2 µg for the Cr(VI) sampled at a flow rate of two liters per minute. A total sampling time of 100 minutes or greater was used to evaluate exposure potentials at an assumed 1 µg/m³ projected PEL (Table 4.2.8).

b. Additional workplace air sampling measurements for Cr(VI) relating to OSHA's anticipated new PEL are needed. The Navy's Consolidated Industrial Hygiene Labotatory (CIHL) at the Navy Environmental Preventive Medicine Unit Two, is currently capable of performing the analytical technique detailed in the OSHA Draft ID-215 "Cr(VI) in Workplace Air" slated to support the anticipated PEL of 0.5 µg/m³. As an interim evaluation, Navy field industrial hygienists will be encouraged to re-sample operations where a negative exposure assessment, using the projected PELs, could not be determined. An additional year of airborne exposure data collection is envisioned.

Based on historical airborne exposure measurements, all of the operations that have been identified to cause a potential exposure to Cr(VI) have the potential for some number of exposures at or above the action level of 0.25 µg/m³ (TWA). Some operations (i.e., Mechanical Cleaning and Painting) are known to present patential exposure problems even at the current ceiling PEL. However, actual workplace evaluations to support control efforts are based on personal breathing zone samples representing site specific parameters

Given the above considerations regarding the evaluation of Cr(VI) exposures basal on previous

9 'Threshold Limit Values for Chemicalq cal Substances and Physical Agents and Biological Exposure Indices," American Conference of Governmental Industrial Hygienists, 1995-1996.

sampling, it is difficult to detemine the impact of the anticipated new OSHA Cr(VI) standard requirements based on similar provisions of the present cadmium standard. One approach is to use past sampling results as a ratio or percentage basis and apply this factor to the need to implement various expected provisions of the anticipated OSHA standard. This is a simple count of the number of samples greater than a given exposure criterion level. Although the limitations of such an assessment are understood, the historical monitoring results may be assessed by the number of Cr(VI) personal breathing zone samples that exceed the anticipated PEL for each operation group and used as a basis to determine impact. As performed for the exposure assessment at the 0.5 µg/m³ level, only samples With a total sample duration greater than or equal to 200 minutes were used. Total sample times greater than or equal to 100 minutes were used for the other (5 and 10 µg/m³) evaluations.

Table 4.2.9 and Table 4.2.10 present the percentage breakdown of samples for the consolidated operation groups. Most operations lack the number of samples to draw statistically significant conclusions. However, the ratio may be used as one indicator of the impact using a potentially exposed base population. These data show as a percentage, the number of personnel affected at the anticipated standard for Cr(VI) would be significantly higher at a PEL of 0.5 µg/m³ compared to higher anticipated PEL's. For example, these data suggest 40% of the welders will be affected at a PEL of 0.5 µg/m³ compared to only 5% at PEL's of 5.0 µg/m³ or 10 µg/m³. The affected population at the proposed action level of 0.25 µg/m³ is unknown. However, it would be expected to be a significantly greater percentage compared to the proposed PEL of 0.5 µg/m³.

Table 4.2.1 Operations Previously sampled with a Potential for Nickel, Manganese, Chromium, and Hexavalent Chromium Exposure Database 1992- June 1995 NAVENVIRHLTHCEN

Operation	Cr and Cr(Vl)	Ni	Mn
CON-001 Construction, Structural Fabrication and Repair	x		
IND-001 Metal Cleaning (includes abrasive blasting, sanding, grinding, needlegunning, etc.)	x	x	x
MIL-001 Military specific operations (i.e., weapons handling, flight line, shipboard, etc.)	x	x	
IND-002/003 Metal Cleaning, Chemical	x	x	
IND-004 Electroplating	x	x	x
IND-005 Painting	x	x	x
IND-006 Coating	x	x	x
IND-007 Metal Forming		x	x
IND-009 Foundry Operations		x	x
IND-010 Metal Machining (including, saving, drilling, milling, turning)		x	x
IND-011 Welding (Resistance, Oxyfuel, Laser, Electron Beam, Brazing, soldering, SMAW, GTAW, PAW, FCAW, SAW, Welder Helpers, Fire watch)	x	x	x
IND-012 Thermal Spraying Arc, flame, Plasma)	x	x	x
INDO-013 Cutting (includes thermal and non-thermal) (Plasma, Air Carbon Arc, Oxyfuel)	x	x	x
IND-020 Woodworking	x	x	
IND-025 - Hazardous Waste Handling	x	x	x
MED Medical Operations (Dental)		x	
SER Services (Transportation, motor vehicle, maintenance)	x	x	

Table 4.2.2 Nickel Exposures ($\mu g/m^3$ TWA)
Navy Occupational Exposure Database
NAVENVIRHLTHCEN

N	Operation	AM	GM	GSD	UTL
229	IND-001 - Metal Cleaning (includes abrasive blasting, sanding grinding, needlegunning, etc.)	126.3	9.8	6.94	236.7
39	MIL - Military Specific Operations (i.e., weapons handling, flight line, shipboard, etc.)	2.2	0.9	4.92	13.7
21	IND-004 - Electroplating	7.7	4.1	2.92	32.4
12	IND-005 - Painting	6.9	3.7	2.99	44.4
6	IND-006 - Coating	10.9	4.1	3.74	364.6
3	IND-007 - Metal Forming	3.9	3.3	1.74	
38	IND-009 - Foundry Operations	2.9	1.8	2.21	7.1
38	IND-010 - Metal Machining (including sawing, drilling, milling, turning)	38.8	4.5	5.13	77.2
333	IND-011- Welding (Resistance, oxyfuel, Laser, electron beam SMAW, GTAW, FCAW, helpers, firewatch)	6.1	3.0	2.74	15.7
40	IND-012 - Thermal Spray, (Arc, Flame, Plasma)	621	6.8	5.26	119.8
36	IND-013 - Cutting (includes thermal, and non-thermal)	304.8	12.1	10.4	690
6	IND-020 - Woodworking	4.8	4.6	1.34	12.4
15	IND-025 - Hazardous Waste Handling	11.2	5.7	2.84	51.3
16	SER - Services (Transportation, motor vehicle, maintenance)	6.9	3.1	4.03	54.7
23	MED - Medical Operations	8.4	4.5	3.23	40.9

Key:
N - Nuber of samples
TWA - Time Weighted Average for an 8 Hour Work Shift - unsampled periods are assumed zero exposure.
AM - Arithmetic Mean
GM - Geometric Mean
GSD - Geometric Standard Deviation
UTL - Uppr Tolerance Lim it (95% confidence that 90% of the population exposures will be below the UTL).

Table 4.2.3 Nickel Exposures During Welding ($\mu g/m^3$ TWA)
Navy Occupational Exposure Database
NAVENVIRHLTHCEN

N	Operation	AM	GM	GSD	**UTL**
29	INDOll-OO- Welding, Multiple Operations	4.6	3.3	2.2	13.9
135	IND-011-01 - Welding, Arc	8.3	3.6	2.91	21.1
6	IND-011-03 - Welding, Oxyfuel	3	2.5	1.76	17.2
48	IND-011-05 - Welding, Brazing	3.1	1.9	2.46	8.5
40	IND-OIl-08- Welding SMAW	7.1	3.7	2.88	23.1
8	IND-011-09 - welding, GMAW	2.9	2.8	1.34	6.2
35	IND-OIl-IO- Welding GTAW	4.5	2.2	2.66	12.8

Key:

N - Number of Samples
TWA - Time Weighted Average for an 8 Hour Work Shift - unsampled periods are assumed zero exposure.
AM- Arithmetic Mean
GM- Geometric Mean
GSD - Geometric Standard Deviation
UTL - Upper Tolerance Limit (95% confidence that 90% of the population exposures will be below the UTL).

Table 4.2.4 Manganese Exposures (µg/m^{3}TWA)
Navy Occupational Exposure Database
NAVENVIRHLTHCEN

N	Operation	AM	GM	GSD	**UTL**
197	IND-001 - Metal Cleaning (includes abrasive blasting, sanding grinding, needlegunning, etc.)	46.6	5.9	7.8	176
2	IND-004 - Electroplating	94	85	1.57	
6	IND-005 - Painting	0.5	0.5	1.13	0.7
1	IND-006 - Coating	3.1	3.1		
2	IND-007 - Metal Forming	7.4	6.3	1.81	
18	IND-009 - Foundry Operations	1.3	1	2.01	5.5
11	IND-010 - Metal Machining (including sawing, drilling, milling, turning)	4.5	2.5	2.76	26.9
380	IND-011 - Welding (Resistance, oxyfuel, Laser, electron beam SMAW, GTAW, FCAW, helpers, firewatch)	53.2	6.9	7.03	171.6
12	IND-012 - Thermal Spray, (Arc, flame, Plasma)	0.97	0.7	1.85	2.9
30	IND-013 - Cutting (includes thermal, and non-thermal)	25.6	3.9	6.94	136.9
5	IND-025 - Hazardous Waste Handling	1.4	1.2	1.75	11.9

Key:
N- Number of samples
TWA - Time Weighted Average for an 8 Hour Work Shift- unsampled periods are assumed zero exposure.
AM- Arithmetic Mean
GM- Geometric Mean
GSD - Geometric Standard Deviation
UTL - Upper Tolerance Limit (95% confidence that 90% of the population exposures will be below the UTL).

Table 4.2.5 Manganese Exposures During Welding ($\mu g/m^3$ TWA)
Navy occupational Exposure Database
N A Y E N V I R H L T H C E N

N	operation	AM	GM	GSD	UTL
22	INDOll-OO- Welding, Multiple Operations	20.1	7.2	5.08	159.1
164	IND-011-01 - welding, Arc	38.2	8.6	6.28	177.5
15	IND-011-03 - Welding, Oxyfuel	6.4	2.5	3.94	44.3
17	IND-011-05 - Welding, Brazing	7	1.6	4.44	32.6
79	IND-011-08 - Welding SMAW	67.7	8.8	7.18	224.6
26	IND-011-09 - Welding, GMAW	24.9	6.1	6.18	175.5
15	INDOll-IO- Welding, GTAW	26	1.2	3.25	14.6

Key

N- umber of Samples
TWA - Time Weighted Average for an 8 Hour Work Shift - unsampled periods are assumed zero exposure.
AMI - Arithmetic Mean
GM - Geometric Mean
GSD - Geometric Standard Deviation
I m - Upper Tolerance Limit (95% confidence that 90% of the population exposures will be below the U-I-L).

Table *4.2.6* Total Chromium Metal Exposures During Welding ($\mu g/m^3$ TWA)
Navy Occupational Exposure Database
NAVENVIRHLTHCEN

N	operation	AM	GM	GSD	**UTL**
31	IND-Oll-OO-Welding, Multiple Operations	3.6	2.6	2.02	9.1
124	IND-011-01-Welding, Arc	5.3	2.3	3.23	16.0
14	IND-011-01-Welding, Arc	12.4	2.1	4.38	50.4
21	IND-011-03-Welding, Brazing	6.3	2.9	2.92	22.6
60	IND-011-08-Welding SMAW	7.2	2.6	3.01	15.9
8	IND-011-09-Welding, GMAW	3.0	2.5	1.75	11.6
29	IND-011-10-Welding, GTAW	3.1	1.8	2.57	10.4
5	INDOII-16-Welding, Flux Core	3.1	2.7	1.70	24.4
12	IND-011-99-Welding, NEC (Not Elsewhere Classified)	2.5	1.9	2.11	10.3

Key

Number of Samples
N- Time Weighted Average for an 8 Hour Work Shif - unsampled periods are assumed zero exposure.
AM- Arithmetic Msan
GM- Geometric Mean
GSD- Geometric Standard Deviation
UTL - Upper Tolerance Limit (95% confidence that 90% of the population exposures will be below the UTL).

Table 4.2.7 Chromium (VI) Exposures (µg/m^3 TWA)
Navy Occupational Exposure Database
NAYENVIRHLHCEN

cr(VI) Samples >199 Minutes

N	Operation	Min	Max.	GM	GSD	**UTL**
3	*CON* - Construction, Structural Fabrication, Repair	0.1	0.11	0.1	1.05	
46	IND-001 - Metal Cleaning (includes abrasive blasting, sanding, grinding, needlegunning, etc.)	0.1	610	1.0	7.28	26.9
4	IND-002 - Metal Cleaning, Chemical	0.1	27	0.6	3.42	
12	IND-004 - Electroplating	0.1	5.0	0.8	3.04	9.8
40	IND-005 - Painting	0.1	*127.8*	*1.9*	*6.13*	*44.1*
5	*IND-006 Coating*	0.1	0.7	0.3	1.88	4.2
15	IND-011Welding (resistance, oxyfuel, laser, electron beam SMAW, GTAW, FCAW, GMAW, helpers, fire watch)	0.1	10.5	0.4	5.9	16.0
8	IND-013 - Cutting (includes thermal, and non-thermal)	0.1	2.0	0.3	2.58	3.4
1	IND-025 - Hazardous Material/Hazardous Waste Handling (includes deanup of industrial areas)	-	-	0.1		
11	SER - Services (transportation, motor vehicle maintenance)	0.2	1.0	0.4	1.85	1.9

Key

N- Number of samples
TWA - Time Weighted Average for an 8 Hour Work Shift - unsampled periods are assumed zero exposure
Min. - Minimum value reported
Max. - Maximum value reported
GM- Geometric Mean
GSD- Geometric Standard Deviation
UTL- Upper Tolerance Limit (95% confidence that 90% of the population exposures will be below the UTL)

Table 4.2.8 Chromiun (VI) Exposures (µg/m³ TWA)
From The Navy Occupational Exposure Database
NAVENVIRHLTHCEN

Cr/VI) Samples >99 Milnutes

N	operation	Min.	Max.	GM	GSD	UTL
4	CON - Construction, Structural Fabrication, Repair	0.1	0.2	0.1	1.37	
74	IND-001 - Metal Cleaning (includes abrasive blasting, sanding, grinding, needlegunning, etc.)	0.1	610	0.9	5.57	15.3
7	IND-002 - Metal Cleaning, Chemical	0.1	27	0.4	3.27	12.4
13	IND-004 - Electroplating	0.1	5.0	0.7	3.03	8.3
68	IND-005 - Painting	0.1	327	1.8	6.17	35.2
9	IND-006 - Coating	0.1	18.3	0.7	4.07	27.6
20	IND-00I - Welding (resistance, oxyfuel, laser, electron beam SMAW, GTAW, FCAW, GNAW, helpers, fire watch)	0.1	10.5	0.3	4.84	7.2
15	IND-013 - Cutting (includes thermnal, and non-thermal)	0.1	4.3	0.3	3.07	2.7
5	IND-025 - Hazardous Material/Hazardous Waste Handling (includes deanup of industrial areas)	0.1	1.7	0.2	3.16	20.9
11	SER - Serivces (transportation, motor vehicle maintenance)	0.2	1.0	0.4	1.85	1.9

Key:

N - Number of samples
lime Wighted Average for an 8 Hour Work Shift - unsampled periods are assured zero exposure
Min.- Minimum value reported
MaX - Maximum value reported
GM - Geometric Mean
GSD - Geometric Standard Deviation
UTL - Upper Tolerance Limit (95% confidence that 90% of the population exposures will be below the UTL)

Table 4.2.9 Percent Samples Exceeding an Anticipated Limit
For Chromium (VI) Personal Breathing Zone Exposure
Navy Occupationall Exposure Database 1992 - June 1995
NAVENVIRHLTHCEN

Cr(VI) >199 Minutes

N	Operatuib	%Samples> 0.5 µg/m^3
3	CON - Construction, Repair, Fabrication	0
46	IND-001 - Metal Cleaning (abrasive blasting, sanding, grinding, needlegunning)	52
4	IND-002 - Metal Cleaning, Chemical	50
12	IND-004 - Electroplating	67
40	IND-005 - Painting	73
5	IND-006 - Coating	40
15	IND-011 - Welding	40
8	IND-013 - Cutting (includes thermal and non-thermal)	25
11	SER - Services (Transportation, motor vehicle, maintenance)	36

Table 4.2.10 Percent Samples Exceeding an Anticipated Limit
For Chromium (VI) Personal Beathing Zone Exposures
Navy Occupational Exposure Database 1992 - June 1995
NAVENVIRHLTHCEN

cr(VI) >99 Minutes

N	Operation	%Samples> 5 µg/m^3	%Samples>
4	CON - Construction, Repair, Fabrication	0	0
74	IND-001 - Metal Cleaning (abrasive blasting, sanding, grinding, needlegunning)	12	9
7	IND-002 Metal Cleaning,	0	0
13	IND-004 - Electroplating	8	0
68	IND-005 - Painting	15	13
9	IND-006 - Coating	0	0
20	IND-011 - Welding	5	5
15	IND-013 - Cutting (includes thermal and non-thermal)	0	0
11	SER - Services (Transportation, motor vehicle, maintenance)	0	0

4.3 Controlled Laboratory Tests of Worker Exposure

Controlled laboratory tests were conducted to measure worker exposure to Ni, Mn, total Cr, and Cr(Vl) during shielded metal arc welding (SMAW) and gas metal arc welding (GMAW using Type 308 austenitic stainless steel consumables in both open and enclosed shop conditions. In addition to tests using general ventilation, these tests evaluated the effectiveness of local exhaust ventilation to reduce worker exposure. Results of these tests provide baseline data under controlled conditions that simulate industrial vvelding operations. Fillet welds were deposited on a low-carbon steel test structure. The use of carbon steel base metal does not have a significant influence on welding fume composition since over 90 percent of the fume comes from the electrode or wire (refer to Section 3.3.2). SMAW was performed with 3/16-inch diameter E308L electrodes using direct current, electrode positive. GHAW was performed with 0.045-inch diameter ER308L electrode wire and argon - 2 percent oxygen shielding gas. Welding parameters were selected to be typical of industrial practice and are listed in Table 4.3.1. Tests were conducted for 4 hours. Actual welding time was approximately 2 hours for each test (50 percent arc time.) Precautions were taken, including the use of multiple welders, to limit individual exposure.

A commercial Iocal exhaust ventilation unit was used for Test No. 2, No. 4, No. 6, No. 7, and No. 8. This local exhaust unit had a rated air flow of 1200 cubic feet per minute (cfm) and a self-cleaning cartridge filter. The open end of the flared exhaust inlet was 12 inches in diameter and was attached to the exhaust unit by 10 feet of 5-1/2 inch diameter flexible duct. The effectiveness of the Iocal exhaust unit to reduce welder exposure was tested under two conditions. During tests No. 2, No. 4, and No. 6, the duct was positioned in the center of the test assembly at a height of approximately 12 inches above the arc and off-set at an angle of approximately 45-degrees. This placement followed recommended practice, including that given in OSHA 29 CFR Part 1910.252. Visual observations during tests No. 2, No. 4, and No. 6 revealed that the local exhaust was only capturing a portion of the fume. Capture effiaency appeared to be high when welding directly under the exhaust duct in the center of the test plate but dropped significantly when welding near the edges of the plate. Therefore, tests No. 7 and No. 8 were conducted using the same welding conditions used for Tests No. 4 and No. 6, except that the local exhaust hood was repositioned during welding so that it remained directly over the area being welded.

Exposure to airborne Cr(VI) was measured in accordance with OSHA analytical Method 215. In addition, air samples were collected and analyzed for Ni, Mn, and total Cr in accordance with NlOSH Method 7300. Four air sampling pumps were used to collect two personal and two area samples for each test rendition listed in Table 4.3.1. Samples were collected for personal and area exposures. The personal samples were collected using helmet sampling adapters placed under the weldet's helmet, in accordance with the ANSI/AWS F1.1[lO]. The area samples were collected on the work table during Tests No. 1,2, and 3 and 48-inches from the arc for Tests No. 4-8. The analytical method recommends that 500 liters of air is an acceptable volume to be sampled. Since the tests were conducted for four hours, the pumps were calibrated at approximately 2 Liters/Minute (2.1 L/Minute x 240 Minutes = 500 Liters).

Results of controlled Iaboratory welder exposure tests are shown in Table 4.3.2. Welder breathing zone results are time-weighted-averages over the 4 hour period tested at arc times of approximately 50%. These results are equivalent to 8-hour TWA's under the same working conditions for 8 hours (i.e. the unsampled periods equal to the sampled periods). These results can be surmmarized as follows

- Only one condition tested, GMAW in an enclosed area with natural ventilation, resulted in worker exposures to Mn (230 µg/m^3) that would exceed new exposure Iimits to Mn.

[10] ANS1/AWS FI.I-92, Method for Sampling Airbome Particulate Generated by Welding and Allied Processes, American Welding Socieiy, Miami, FL 1992.

- While none of the tests produced exposures that exceeded the existing limit for total Cr, SMAW and GMAW in an enclosed area with natural ventilation had the highest exposures for this element.

- None of the tests produced welder exposures to Ni that exceeded 30% of the anticipated new ACGIH exposure limit.

- SMfAW in the open and SNAW and GMAW in enclosed areas produced Cr(Vl) exposures that exceeded 5µg/m^3 levels when local exhaust ventilation was not used.

- Local exhaust ventilation rduced welder exposure by more than 50 percent compared to natural ventilation. However; unless local exhaust ventilation was carefully positioned above the welding arc, exposure levels for Cr(Vl) remained above 2 µg/m^3 for both SMAW and GMAW under the conditions tested.

- Only a single GMAW test with the optimum local exhaust ventilation conditions reduced Cr(Vl) to below 0.5 µg/m^3.

- Only a single SMAW test with the optimum local exhaust ventilation conditions reduced levels of Cr(Vl) to 0.5 µg/m^3.

- Area samples show that for many of the conditions tested, workers within 4 feet of the welding arc may be exposed to Cr(Vl) above 0.5 µg/m^3.

While the laboratory tests represent single data points for each test condition, the results of these tests are in agreement with the shipyard welder exposure samples reported in Section 4.5. The laboratory test result of 13 µg/m^3. (Test No. 1) measured during SMAW in an open area with natural ventilation is within the range of values reported in Table 4.5.4 under similar conditions. The Test No. 2 value of 2 µg/m^3, measured in the laboratory for SMAW in an open area using local exhaust ventilation also falls within the range of 0.1-40 µg/m^3 measured in the shipyard under similar conditions. Laboratory results for GMAW are higher than the shipyard data, which may be attributable to the fact that the laboratory tests were conducted in enclosed renditions. In addition, laboratory test results may be high due to the 50 percent arc time used for these tests which is higher than the 15 to 35 percent arc time typical of many industrial welding operations. The laboratory tests indicate that local exhaust ventilation must be very carefully positioned in order to reduce welder expsures to Cr(VI) to 0.5 µg/m^3. Local exhaust ventilation appears to be more effective in controlling exposure at a PEL of 5.0 µg/m^3. This conclusion agrees with that reported in the AWS tests discussed in Section 4.1. Further testing under industrial conditions is needed to determine the ability of local exhaust ventilation to consistently control exposure at a PEL of 0.5µg/m^3.

Table 4.3.1 Laboratory Fume Exposure Measurement Test Parameters

Test Number	Process	Consumables	Average Current [amps]	Average Voltage [volts]	Average Wire Feed Speed [ipm]	Weight Electrodes consumed [lbs]	Total Arc Time [min]	Open/ Enclosed	Ventilation
1	SMAW	E308L	170	30	-	12.4	116	Open	Natural
2	SMAW	E308L	130	26	-	10.3	120	Open	Stationary Local Exhaust
3	SMAW	E308L	130	25	-	11.5	120	Enclosed	Natural
4	SMAW	E308L	170	30	-	12.8	119	Enclosed	Stationary Local Exhaust
5	GMAW	ER308L Ar-2%O_2	200	26	280	12.5	97	Enclosed	Natural
6	GMAW	ER308L Ar-2%O_2	170	26	260	14.3	120	Enclosed	Stationary Local Exhaust
7	GMAW	ER308L Ar-2%O_2	180	27	265	14.5	120	Enclosed	Positioned Local Exhaust
8	SMAW	E308L	195	27	-	10.8	109	Enclosed	Positioned Local Exhaust

Note: Base material for all tests was low-carbon steel.

Table 4.3.2 Results of Laboratory Fume Exposure Measurement Tests
Results are 4-hour time-weighted-averages at approximately 50% arc time

Test Number	Process	Open/ Enclosed	Ventilation	Welder's Breathing Zone ($\mu g/m^3$)	Area Sample ($\mu g/m^3$)
1	SMAW	Open	Natural	Cr(VI) = 13 Cr = 38 Mn = 31 Ni = 4.1	Cr(VI) = 13 Cr = 16 Mn = 31 Ni = < 3.9
2	SMAW	Open	Stationary Local Exhaust	Cr(VI) = 2 Cr = 4.4 Mn = 5.2 Ni = < 3.9	Cr(VI) = 11 Cr = 15 Mn = 15 Ni = < 3.9
3	SMAW	Enclosed	Natural	Cr(VI) = 160 Cr = 160 Mn = 150 Ni = 10	Cr(VI) = 9.8 Cr = 15 Mn = 14 Ni = < 3.9
4	SMAW	Enclosed	Stationary Local Exhaust	Cr(VI) = 4.1 Cr = 13 Mn = 12 Ni = < 3.9	Cr(VI) = 28 Cr = 36 Mn = 31 Ni = < 3.9
5	GMAW	Enclosed	Natural	Cr(VI) = 13 Cr = 110 Mn = 230 Ni = 29	Cr(VI) = 20 Cr = 100 Mn = 220 Ni = 27
6	GMAW	Enclosed	Stationary Local Exhaust	Cr(VI) = 3.9 Cr = 36 Mn = 73 Ni = 13	Cr(VI) = 1 Cr = 21 Mn = 45 Ni = 5.4
7	GMAW	Enclosed	Positioned Local Exhaust	Cr(VI) = < 0.2 Cr = 24 Mn = 37 Ni = 6.2	Cr(VI) = < 0.2 Cr = 7.8 Mn = 12 Ni = < 3.9
8	SMAW	Enclosed	Positioned Local Exhaust	Cr(VI) = 0.54 Cr = 4.4 Mn = 5.4 Ni = < 3.8	Cr(VI) = 0.99 Cr = 4.2 Mn = 4.8 Ni = < 3.6

Area samples taken on work bench for Tests No. 1,2,3 and 4 feet away for Tests No. 4-8.

4.4 Worker Exposure Sampling Plan

The objective of the worker exposure sampling conducted by the Task Group was to identify the shipyard welding, cutting, gouging, and grinding operations that have a high potential for worker exposure at or above the new and antiapated exposure limits for Ni, Mn, total Cr, and Cr(Vl). Two types of sampling were planned

- Screening samples of a tide range of “high risk” operations have been gathered and are reported here.
- Multiple sampling of selected “high risk” operations will continue in the future.

Sampling is intended to provide baseline data to assess whether or not current technology can feasibility reduce exposure levels to below the new and anticipated exposure levels. The analysis of previous data indicates that the anticipated change in Cr(VI) exposure level may have the greatest potential impact on shipbuilding operations and welding, cutting, grinding, and gouging operations would be among those most affected. Therefore, most of the shipyard worker exposure samples involved welding, cutting, and grinding of chromium bearing materials using these processes. Since the scope of the screening sampling was limited by the time available, the Task Group was unable to sample a representative fraction of the employees at any participating site nor does this sampling prove or disprove compliance of any site or opration. The Task Group will continue to gather worker exposure samples and will report these when results become available.

Sampling was based on the selection of the maximum risk employees involved in welding, thermal cutting, gouging, and grinding operations in three private shipyards. The majority of sampling was conducted on the employees actually performing the operations since they are closest to the source of the potentially hazardous material being generated. limited area sampling also was performed.

High risk operations, where exposure is expected to be the highest were selected in the following manner

- The Navy worker exposure database was reviewed (See Section 4.2) and operations were identified that showed exposure to Ni, Mn, total Cr, and Cr(VI).
- Several private shipbuilders reviewed their databases and identified operations with Potential for exposure to Ni, Mn, total Cr, and Cr(Vl).
- Literature was reviewed, including a report prepared for the Environmental Protection Agency, to identify sources of hazardous emissions from arc welding[11].

Table 4.4.1 lists the materials and operations selected for screening sampling of vvorker exposure to Ni, Mn, total Cr, and Cr(VI). The table shows that some operations were sampled by more than one organization to confirm these data through replication. A limited nunker of screening samples were gathered on some operations and materials. This table also shows the operations where further sampling is needed.

Personal air samples were collected in the worker's breathing zone according to ANSI/AWS F1.1 to determine full shift exposures. Sampling cassettes were placed inside the welders helmet during welding, and inside the shield during cutting, gouging, and grinding operations. The cassette was placed in the worker'sket’s breathing zone for operations that did not use a shield. Analysis of Ni, Mn, and total Cr vvas performed to NIOSH Procedure 7300. Analysis of Cr(Vl) was perfomed to draft OSHA Method 215.

---

[11] Develoment of Particulate and Harzardous Emisssion Factors for Electric Arc Welding AP-42 Section 12.19, Final Report, U.S. Environmental Protection Agency Office of Air Quality planning and Standards Emission Inventory Branch Contract No. 68-D2-0159 Work Assignment No. 12, April 25, 1994.

Table 4.4.1 Shipyard Screening Sampling of Worker Exposure

Materials							
CRES S-8	HY-100 HY-80 S-11A	HSLA80 S-11C	HSLA100 S-11D	Carbon Steel S-1 Painted	Nickel Alloy 600/625	Cu-Ni	Ni-Cu
C, A	A	C	C		A	A	A
B,A	C	C,A	C		B,A	A	A
C, A	C,A				A	A	A
	XXXXXXXXXXXXXX				XXXXXXXXXXXX	XXXXXXXXXXX	XXXXXXX
A	A				A	-	A
C	C	-	-	C	XXXXXXXXXXXX	XXXXXXXXXXX	XXXXXXX
	A				XXXXXXXXXXXX	XXXXXXXXXXX	XXXXXXX
	A				A	A	A
C	A			C	A	A	A

nples under all conditions
nples under all conditions
nples under all conditions

Complete process, environment, and sampling data were recorded on a form quivalent to that in ANS1/AW3 F1.1. Data indudect:

- Description of the opration (when and where).
- Environment (open, enclosed, confined space as well as ventilation).
- Base metal and matings or contaminats on the surface.
- Welding materials and consumables (welding electrode, shielding gas, etc.).
- Welding parameters
- Operating renditions (welding time, other operations performed by the welder, etc.)
- Engineering controls in use.
- Sampling data (filters, pump, flow rates, times, weight of material, etc)
- Results (total measured fume quantities and TWA values for total fume, Ni, Mn, total Cr and cr(Vl).

The results of these screening samples are given in Section 4.5.

4.5 Results of Shipyard Worker Exposure sampling

Worker exposure sampling was conducted in three private shipyards (Navy contractors) to evaluate levels of Ni, Mn, total Cr, and Cr(Vl). This "screening sampling of selected high-risk operations" (welding, Cutting, gouging, grinding, casting, and electroplating) vvas performed according to the sampling plan outlined in Section 4.4. Personal air samples were collected in the breathing zone of the workers. Sampling cassettes were placed inside the welding helmet and in the worker's breathing zone for operations that did not use a helmet or shield. Analysis of Ni, Mn, and total Cr was performed to NlOSH Procedure 7300. Analysis of Cr(Vl) was performed to draft OSHA Method 215.

Table 4.5.1, Table 4.5.2, and Table 4.5.3 contain the details and results of the shipyard worker exposure samples. All of the shipyard data on Cr(VIl) are summarized in Table 4.5.4. Table 4.5.5 summarizes all of the worker air samples for Ni, Mn, and total Cr. The results of all of these samples can be described as follows

- Welders performing SMAW of stainless steel and high-chromium, nickel alloys may be exposed to Cr(Vl) in excess of 5 $\mu g/m^3$ either with or without use of local exhaust ventilation. Workers in areas where SMAW is being performed with these materials also may be exposed to Cr(Vl) at levels of over 1 $\mu g.m^3$ and as high as 5 $\mu g/m^3$. While limited area samples were taken for SMAW of stainless steels, laboratory tests reported earlier indicate a similar risk for this process and material also may occur in shipyards.

- Welders performing GMAW of high-chromium nickel alloys may be exposed to Cr(M) in excess of 2 $\mu g.m^3$ either with and without use of local exhaust ventilation.

- Shipyard samples did not show that local exhaust ventilation significantly reduced exposure compared to general ventilation for SMAW of stainless steel or high-chromium nickel alloys. Controlled laboratory tests and literature suggest local exhaust ventilation should significantly reduce fume exposure when properly used. However, even under the best of conditions it may not be possible to achieve Cr(Vl) exposure levels of 0.5 $\mu g/m^3$ for SMAW of stainless steels and high-chromium nickel alloys due to workplace constraints that may limit the effectiveness local exhaust ventilation in actual practioe.

- Welders performing SMAW of HY80 and HYI00 low-alloy steels vvere, in some cases exposed to Cr(Vl) at levels as high as 2 $\mu g/m^3$. This is in spite of the fact that the chromium levels in the welding electrodes used for these tests are low (0.I% Cr in El 1018 and 0.3% Cr in E12018.) This area needs further study because of the widespread use of these steels by the Navy.

- Welders perfoming GMAW of HY80 and HY100 Iow-alloy steels may be exposed to Cr(Vl) in excess of 0.25 µg/m^3 without use of local exhaust ventilation.

- Welders perfoming GTAW of stainless steel may be exposed to Cr(Vl) in excess of 0.25 µg/m^3 without use of local exhaust ventilation.

- GMAW of high-chromium, nickel alloys in endosed spaces at one shipyard resulted in Ni exposures exceeding 100 µg/m^3. While other tests were below the new and anticipated exposure limits for Ni and Mn, SMAW of nickel alloys, stainless steels, HY80 and HY100 steels and GMAW of stainless steels have the highest recorded exposures to these elements.

Examination of the worker exposure samples (Table 4.5.1 through Table 4.5.5) shows the inherent variability of this type of data. It is not unusual for these data to vary by more than an order of magnitude. While many samples are near the lower limit of measurement, there area few very high data points. Industrial hygienists recognize this "lognonnal" distribution for worker sampling data. The wide range of results is caused by the variability of factors that influence these operations. For example, welding operations represent a wide range of arc tires, the time during which fume is actually produced over the 8-hour weighting period. Welding position and the position of the welder's head relative to the fume are additional variables. There also is variability in the degree of enclosure or confinement in areas that are described as endosed and confined spaces, in spite of the attempts to provide standard definitions. The degree of variability in the use of local exhaust ventilation is documented in these tests as well as in the controlled laboratory tests described earlier. As indicated during the sampling plan, these screening samples are not sufficient to characterize any operation, but only identify those with the high potential exposure.

Table 4.5.1 Personal and Area Air Sampling Data - Shipyard "A"

Sample	Type of Space	Site	Process	Base Metal	Filler Metal	NIOSH 7300 8-Hour TWA (μg/m³)			OSHA METHOD 215 Cr VI TWA (μg/m³)	Ventilation
						Ni	Mn	Cr(total)	Cr(VI)	
14899	0	LAB	SMAW	INCONEL 600	8N12 (0.125)	56.8	121.8	29.5		NONE
15103	O	LAB	SMAW	INCONEL600	8N12 (0.125")				1.8	NONE
15102	O	LAB	SMAW	INCONEL600	8N12 (0.125)	3	6.5	2		
15029	O	LAB	SMAW	INCONEL600	8N12 (0.125")				2.7	NONE
15032	O	LAB	SMAW	INCONEL600	8N12 (0.125")	33.1	50.1	13.5		
14905	O	LAB	SMAW	INCONEL625	1N12 (0.125")	2.5	6.3	20.6		NONE
15017	O	LAB	SMAW	INCONEL625	1N12 (0.125")				23.5	NONE
15123	O	LAB	SMAW	INCONEL625	1N12 (0.125")				30.2	NONE
15124	O	LAB	SMAW	INCONEL625	1N12 (0.125")	27.3	1.9	31.6		
15239	O	QP	SMAW	INCONEL625	1N12 (0.156")				57.9	NAT.DIL.
14909	O	LAB	SMAW	CRES 304	309CB (1/8")	3.3	25.5	12.3		NONE
14989	O	LAB	SMAW	CRES 304	309CB (1/8")				5.7	NONE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]
15043	O	LAB	SMAW	CRES 304	309 CB (1/8")	0.7	3.9	2.9		
15097	0	LAB	SMAW	CRES 304	3309CB (1/8")				24.2	NONE
15096	O	LAB	SMAW	CRES 304	309 CB (1/8")	5.2	46.5	33.6		NONE
15098	E	BOAT	SMAW	CRES 304	309CB (3/32")				2.1	

All Samples are Personal Samples, Unless Otherwise Indicated. Area Samples Appear on Last Two Pages of This Table.

E = Enclosed O = Open C = Confined

Table 4.5.1 (Cont.) Personal and Area Air Sampling Data - Shipyard "A"

Sample	Type of Space	Site	Process	Base Metal	Filler Metal	NIOSH 7300 8-Hour TWA (µg/m³)			OSHA METHOD 215 Cr VI TWA (µg/m³)	Ventilation
						Ni	Mn	Cr(total)	Cr(VI)	
15065	E	BOAT	SMAW	CRES309	309CB (3/32")				40	NONE
15083	O	BOAT	SMAW	CRES309	309CB (3/32")				12.3	NONE
15084	E	BOAT	SMAW	CRES309	309CB (3/32")				<0.1	NONE
15131	E	BOAT	SMAW	CRES309	309CB (3/32")				0.6	NONE
15177	E	BOAT	SMAW	CRES309	309CB (3/32")				4.6	NONE
15180	E	BOAT	SMAW	CRES309	308L (3/32")				25.4	NONE
15276	O	BOAT	SMAW	CRES309	309CB (3/32")	3.2	25.2	0.2		NAT. DIL.
15167	E	BOAT	SMAW	309 TO HTS	309CB				6.1	NONE
15179	E	BOAT	SMAW	309 TO HTS	309CB				0.2	LOCAL
15281	O	BOAT	SMAW	309 TO HTS	308L				<0.1	NAT. DIL.
14978	O	LAB	SMAW	HY 80	11018M (0.045")	3.1	35.1	2.1		NONE
15178	E	BOAT	SMAW	HY80	11018MR (3/32")				1.4	NONE
15212	E	BOAT	SMAW	HY80	11018MR (3/32")				<0.1	NONE
15213	E	BOAT	SMAW	HY80	11018MR (1/8")				<0.1	NONE
15214	O	BOAT	SMAW	HY80	11018MR (3/32")				2.2	NAT.DIL.
15235	E	BOAT	SMAW	HY80	11018MR (3/32")				<0.1	NONE
15233	E	BOAT	SMAW	HY80	11018MR (3/32")				<0.1	NONE
15309	E	BOAT	SMAW	HY80	11018MR (3/32")				<0.1	NONE
15368	E	BOAT	SMAW	HY80	11018MR (1/8")				1	NONE
15369	E	BOAT	SMAW	HY80	11018MR (1/8")	5	9.8	1		NONE
15336	E	BOAT	SMAW	HY80	11018MR (1/8")				0.8	LOCAL
15337	E	BOAT	SMAW	HY80	11018MR (1/8")	2.6	52.2	1.3		LOCAL

All Samples are Personal Samples, Unless Otherwise Indicated. Area Samples Appear on Last Two Pages of This Table.

E = Enclosed O = Open C = Confined

Table 4.5.1 (Cont.) Personal and Area Air Sampling Data - Shipyard "A"

Sample	Type of Space	Site	Process	Base Metal	Filler Metal	NIOSH 7300 8-Hour TWA ($\mu g/m^3$)			OSHA METHOD 215 Cr VI TWA ($\mu g/m^3$)	Ventilation
						Ni	Mn	Cr(total)	Cr(VI)	
[redacted]										
15166	E	BOAT	SMAW	HY100	11018MR (3/32")				0.2	NONE
15240	O	SHOP	SMAW	HY100	11018MR (3/32")				0.4	NAT.DIL.
15315	C	BOAT	SMAW	HY100	11018MR (1/8")				0.7	LOCAL
15314	O	BOAT	SMAW	HY100	11018MR (1/8")				0.2	NAT. DIL.
15313	O	BOAT	SMAW	HY100	11018MR (1/8")	2.2	52.6	1.2		NAT. DIL.
15307	E	BOAT	SMAW	HTS	7018MR (3/32")				<0.1	NONE
15308	E	BOAT	SMAW	HTS	7018MR (3/32")	0.2	4.9	0.2		NONE
14904	O	LAB	SMAW	Ni Cu	9N10	64.8	45.3	0.8		NONE
14912	O	LAB	SMAW	Cu Ni	187N (0.125")	7.8	6.9	1.3		NONE
14913	O	LAB	GMAW (spray)	INCONEL625	INC 625 (0.045")	98.5	4.5	24.2		NONE
15018	O	LAB	GMAW (pulse)	INCONEL625	INC 625 (0,045")				0.3	NONE
14977	O	LAB	GMAW (pulse)	CRES 304	309CB (0.045")	10.4	16.6	16.6		NONE
14990	O	LAB	GMAW (pulse)	CRES 304	309 (0.045")				0.7	NONE
14915	O	LAB	GMAW (pulse)	Cu Ni	CUNI 67 (0.045")	7.6	3.6	0.7		NONE
14988	O	LAB	GMAW (pulse)	NiCu	MONEL 60N (0.045")	42.2	12.7	2.3		NONE
15365	E	BOAT	GMAW (pulse)	HY80	100S-1 (0.045")				<0.1	NONE
15355	E	BOAT	GMAW (pulse)	HY80	100S-1 (0.045")				0.1	NONE

All Samples are Personal Samples, Unless Otherwise Indicated. Area Samples Appear on Last Two Pages of This Table.

E = Enclosed O = Open C = Confined

Table 4.5.1 (Cont.) Personal and Area Air Sampling Data - Shipyard "A"

Sample	Type of Space	Site	Process	Base Metal	Filler Metal	NIOSH 7300 8-Hour TWA (µg/m³)			OSHA METHOD 215 Cr VI TWA (µg/m³)	Ventilation
						Ni	Mn	Cr(total)	Cr(VI)	
15390	E	BOAT	GMAW (pulse)	HY80	100S-1 (0.045")				<0.1	NONE
15393	E	BOAT	GMAW (pulse)	HY80	100S-1 (0.045")				<0.1	NONE
15356	E	BOAT	GMAW (pulse)	HTS	70S-3 (0.045")				<0.1	NONE
15225	C	BOAT	GMAW (pulse)	HTS	70S-3 (0.045")				0.1	LOCAL
[illegible]	E	LAB	GTAW	INCONEL600	67N (0.062")	3.2	14.1	2.2		NONE
15016	E	LAB	GTAW	INCONEL600	82T (0.062")				<0.1	NONE
14903	E	LAB	GTAW	INCONEL625	INC 625 (0.062")	3.6	4.2	2.6		NONE
15027	E	LAB	GTAW	INCONEL625	INC 625 (1/16")				<0.1	NONE
15041	E	LAB	GTAW	INCONEL625	INC 625 (0.062")				<0.1	NONE
15044	E	LAB	GTAW	INCONEL625		0.8	1.2	1.2		NONE
14917	E	LAB	GTAW	CRES 304	309 (1/16")	1.5	2.7	0.6		NONE
14991	E	LAB	GTAW	CRES 304	309 (1/16")				0.4	NONE
15082	O	SHOP	GTAW	CRES 304	308L (0.062")				<0.1	NONE
15085	E	LAB	GTAW	CRES 304	309 (1/16")				0.2	NONE
15086	E	LAB	GTAW	CRES 304	309 (1/16")	0.5	9.4	1.2		NONE
15088	O	LAB	GTAW	CRES 304	309 (1/16")				0.2	NONE
15087	O	LAB	GTAW	CRES 304	309 (1/16")	1.8	29.2	4.6		NONE
15327	O	SHOP	GTAW	CRES 304	308L (1/16")				<0.1	LOCAL
15326	0	SHOP	GTAW	CRES 304	308L (1/16")	<0.2	<0.2	<0.2		LOCAL

All Samples are Personal Samples, Unless Otherwise Indicated. Area Samples Appear on Last Two Pages of This Table.

E = Enclosed O = Open C = Confined

[redacted]

14976	E	LAB	GTAW	INCO C-276	C-276 (0.062")	2.8	5.5	1.1		NONE
15030	E	LAB	GTAW	INCO C-276	C-276 (1/16")				0.3	NONE
15031	E	LAB	GTAW	INCO C-276	C-276 (1/16")	2	5.1	2.1		NONE
15039	E	LAB	GTAW	HY 80	100S-1 (0.062")				<0.1	NONE
15040	E	LAB	GTAW	HY 80	100S-1 (0.062")	0.8	10.3	1		NONE
14910	E	LAB	GTAW	Cu Ni	67N (0.62")	2.9	13.2	6.3		NONE
15064	E	LAB	GTAW	Cu Ni	67N (0.062")				<0.1	NONE
15063	E	LAB	GTAW	Cu Ni	67N (0.062")	0.4	1.9	0.3		
14987	E	LAB	GTAW	Ni Cu	RN60 (0.062")	1.1	2.4	0.2		NONE
14914	O	LAB	SAW	INCONEL625	INC 625 (0.062")	1	1.1	0.5		NONE
15002	O	LAB	SAW	CRES 304	309 (1/16")	0.8	1.3	0.3		NONE
15003	O	LAB	SAW	CRES 304					<0.1	
15226	O	SHOP	GTAW	NiCu to HY100	60N (0.062")				<0.2	

All Samples are Personal Samples, Unless Otherwise Indicated. Area Samples Appear on Last Two Pages of This Table.

E = Enclosed O = Open C = Confined

Table 4.5.1 (Cont.) Personal and Area Air Sampling Data - Shipyard "A"

Sample	Type of Space	Site	Process	Base Metal	Filler Metal	NIOSH 7300 8-Hour TWA (µg/m³)			OSHA METHOD 215 Cr VI TWA (µg/m³)	Ventilation
						Ni	Mn	Cr(total)	Cr(VI)	
14916	O	LAB	SAW	HY 80/100	100S-1 (3/32")	1.6	3.4	0.8		NONE
15019	O	LAB	SAW	Ni Cu	60N (0.062")				<0.1	NONE
ALLIED PROCESSES										
15165	E	BOAT	GRINDING	HY80/100 & HTS					0.2	SHIP VENT.
15181	E	BOAT	GRINDING	HY80					<0.1	NONE
15344	O	BOAT	GRINDING	HY80					<0.1	
15343	O	BOAT	GRINDING	HY80		5.2	13.7	2		NAT. DIL.
15305	E	BOAT	BURNING	HY80					0.1	NONE
15250	E	BOAT	BURNING	HY80					0.3	NONE
15249	E	BOAT	BURNING	HY80		60	7.4	9.3		NONE
15306	E	BOAT	BURNING	HY80		15.2	5.4	1.9		NONE
15260	E	CRANE	STEEL PREP	PAINTED STEEL						
15259	0	CRANE	STEEL PREP	PAINTED STEEL					0.7	LOCAL
15312	0	GD #1	STEEL PREP	PAINTED STEEL		<0.2	1	0.8		NAT. DIL.
15311	0	GD #1	STEEL PREP	PAINTED STEEL		<0.2	0.8	0.4		NAT. DIL.
AREA SAMPLES										
15237	O	SHOP	SMAW	INCONEL625					5.4	NAT.DIL.
15242		SHOP	(CLADDING)	OVER HY100		12.7	1	9.3		

All Samples are Personal Samples, Unless Otherwise Indicated. Area Samples Appear on Last Two Pages of This Table.

E = Enclosed O = Open C = Confined

15339	E	BOAT	SMAW	HY80					1.4	
15338	E	BOAT	SMAW	HY80		5	147.5	1.9		LOCAL
15227	C	BOAT	GMAW	HTS					<0.1	LOCAL
15357	E	BOAT	GMAW	HTS					<0.2	NONE
15358	E	BOAT	GMAW	HTS		0.8	34.5	0.4		
15367	E	BOAT	GMAW	HY80		8.0	39.9	1.4		NONE
15366	E	BOAT	GMAW	HY80					0.2	NONE
15391	E	BOAT	GMAW	HY80					0.1	NONE
15329	O	SHOP	GTAW	CRES 304					<0.1	LOCAL
15328	O	SHOP	GTAW	CRES 304		<0.2	<0.2	<0.2		LOCAL
15274	E	BOAT	GTAW	CRES 304					<0.1	SHIP VENT.
15275	E	BOAT	GTAW	CRES 304		0.7	4.3	0.5		
15388	E	BOAT	GTAW	CRES 304					<0.1	SHIP VENT.

All Samples are Personal Samples, Unless Otherwise Indicated. Area Samples Appear on Last Two Pages of This Table.

E = Enclosed O = Open C = Confined

Table 4.5.2 Personal and Area Air Sampling Data - Shipyard 'B'

Sample	Type of Space	Process	Filler/Base	NIOSH 7300 8- Hour TWA (μg/m³)			OSHA Method 215 (μg/m³)	Ventilation	Monitoring Type
				Ni	Mn	Cr(total)	Cr(VI)		
H95220-1	Confined	GMAW	EN625 on CRES				2.2	Local	Personal
H95220-2	Enclosed	"	"				0.85	None	"
H95220-3	"	"	"				0.76	"	"
H95220-4	"	"	"				0.48	"	"
H95220-5	"	"	"				0.04	Natural	Area
H95220-6	"	"	"				0.07	"	"
H95220-7	"	"	"	26	3.8	12		"	"
H95220-8	"	"	"	15	7.4	8.4		"	"
H95221-1	Enclosed	GMAW	EN625 on CRES				1.6	None	Personal
H95221-2	"	"	"				1.9	"	"
H95221-3	"	"	"				1.3	"	"
H95221-4	"	"	"				0.4	"	"
H95221-5	"	"	"				0.06	Natural	Area
H95221-6	"	"	"	1290	0.7	380		None	Personal
H95221-7	"	"	"	150	10	90		"	"
H95221-8	"	"	"	100	6.9	48		"	"
H95221-9	"	"	"				<0.02	N/A	Blank
H95221-10	"	"	"	1	<.5	<1		N/A	Blank

Sample	[redacted]
H95227-1	
H95227-2	
H95227-3	
H95227-4	
H95227-5	
H95227-6	
H95227-7	
H95227-8	
H95227-9	
H95228-1	
H95228-2	
H95228-3	
H95228-4	
H95228-5	
H95228-6	
H95228-7	
H95228-8	
H95228-9	

Table 4.5.2 (Cont.) Personal and Area Air Sampling Data - Shipyard "B"

Sample	Type of Space	Process	Filler/Base	NIOSH 7300 8- Hour TWA (μg/m³)			OSHA Method 215 (μg/m³)	Ventilation	Monitoring Type
				Ni	Mn	Cr(total)	Cr(VI)		
H95229-1	Enclosed	GMAW	EN625 on CRES				2.0	None	Personal
H95229-2	"	"	"	310	4.4	120		"	"
H95229-3	Confined	"	"				1.2	Local	"
H95229-4	"	"	"	160	41	110		"	"
H95229-5	Enclosed	"	"				0.6	None	"
H95229-6	"	"	"	·370	3	130		"	"
H95229-7	"	"	"				0.5	"	"
H95229-8	"	"	"	270	5.4	110		"	"
H95229-9	"	"	"				<0.02	N/A	Blank
H95229-10	"	"	"	<1	.5	<1		N/A	Blank

Table 4.5.3 Personal Air Sampling Data - Shipyard "C"

Sample	Process	Base/Filler	Type of Space	Ventilation	Cr(VI) Exposure (µg/m³)	Sampling Time/min	OSHA Method 215 8-hr TWA Cr(VI) Exposure (µg/m³)
170-1	GMAW-pa	HY100 / 100s	Encl	Pos	0.16	374	0.12
170-3	GMAW-pa	HY100 / 100s	Encl	Pos	<0.13	385	<0.10
170-5a	GMAW-pa	HY100 / 100s	Encl	Pos	<0.31	191	———
170-7a	GMAW-pa	HY100 / 100s	Encl	Pos	<0.35	165	<0.24
186-6	GMAW-pa	HY80 / 100s	Encl	Pos	0.16	374	0.12
186-8	GMAW-auto	HY80 / 100s	Encl	Pos	<0.14	365	<0.11
188-10	GMAW-pa	HY80 / 100s	Encl	Pos	0.23	338	0.16
188-11	GMAW-pa	HY80 / 100s	Encl	Pos	<0.13	385	<0.10
188-14b	GMAW-pa	HY80 / 100s	Encl	Pos	<0.28	175	<0.21
191-18	GMAW-pa	HY80 / 100s	Encl	Pos	<0.41	130	<0.31*
192-20	GMAW-pa	HY80 / 100s	Encl	Pos	<0.13	396	<0.11
192-21	GMAW-pa	HY80 / 100s	Encl	Pos	0.30	398	0.25
192-22	GMAW-pa	HY80 / 100s	Encl	Pos & Neg	<0.26	188	<0.10
194-24	GMAW-pa	HY80 / 100s	Encl	Pos	0.20	406	0.17
194-25	GMAW-pa	HY80 / 100s	Encl	Pos	<0.24	215	<0.11
195-27	GMAW-pa	HY80 / 100s	Encl	Pos	0.23	388	0.19
195-28	GMAW-pa	HY80 / 100s	Encl	Pos	<0.14	364	0.11
195-29	GMAW-pa	HY80 / 100s	Conf	Pos & Neg	<0.20	260	<0.11
188-13b	AAC	HY80	Encl	Pos	<2.1	25	———

Table 4.5.3 (Cont.) Personal Air Sampling Data - Shipyard "C"

Sample #	Process	Base/Filler	Type of Space	Ventilation	Cr(VI) Exposure ($\mu g/m^3$)	Sampling Time/min	OSHA Method 215 8-hr TWA Cr(VI) Exposure ($\mu g/m^3$)
191-16c	AAC	HY80	Encl	Pos & Neg	<0.28	187	———
191-17c	AAC	HY80	Encl	Pos & Neg	<0.38	130	<0.21
241-94a	AAC	HTS / Cr paint	Encl	Neg	8.6	91	13.0
203-37	SMAW	HY100 / 11018	Encl	none	2.4	255	1.3
203-38	SMAW	HY100 / 11018	Encl	none	<0.14	330	<0.10
201-33	SMAW	HY100 / 11018	Open	none	0.26	375	0.20
204-40	SMAW	HY100 / 11018	Open	none	>0.56	300	>0.35
204-41	SMAW	HY100 / 11018	Open	none	<0.16	301	<0.10
207-44	SMAW	HY100 / 11018	Open	none	<0.12	383	<0.10
210-50	SMAW	HY100 / 11018	Open	natural	0.81	367	0.62
210-51	SMAW	HY100 / 11018	Open	natural	0.64	341*	0.54‡
212-54	SMAW**	HY100 / 11018	Open	natural	0.56	397*	0.52‡
212-55	SMAW	HY100 / 11018	Open	natural	0.37	406*	0.33‡
208-47	SMAW	SS / 309	Open	natural	>10.0	358*	>8.5‡
212-53	SMAW	SS / 309	Open	natural	44.0	370	34.0
217-57	SMAW	SS/m / 308,309	Encl	pos	62.0	416	54.0
220-59	SMAW	SS/m / 309	Encl	pos	14.0	377	11.0
221-65	SMAW	SS / 410	Open	gen mech	45.0	389*	38.0

Table 4.5.3 (Cont.) Personal Air Sampling Data - Shipyard "C"

Sample #	Process	Base/Filler	Type of Space	Ventilation	Cr(VI) Exposure (µg/m³)	Sampling Time/min	OSHA Method 215 8-hr TWA Cr(VI) Exposure (µg/m³)
225-72	SMAW	SS / 410	Open	gen mech	33.0	367	25.0
227-82	SMAW	SS / 410	Open	gen mech	9.6	286*	6.2
229-85	SMAW	SS / 410	Open	gen mech	2.4	385*	2.0
229-86	SMAW	SS / 410	Open	gen mech	2.0	248	1.0
240-90	SMAW	SS / 410	Open	gen mech	1.4	401*	1.2
199-31	GTAW-auto	CuNi	Open	Shop	<0.94	54	<0.11
201-36	GTAW	SS /316	Open	none	<0.12	118	<0.03
220-60	GTAW	SS / 308	Encl	neg	<0.21	244	<0.03
221-62	GTAW	SS / 308	Encl	neg	<0.12	410	<0.11
221-67	GTAW	SS / 308	Encl	neg	0.21	390	0.17
222-70	GTAW	SS / 308	Encl	neg	<0.12	412	0.10
227-81	GTAW	SS / 316	Encl	neg	<0.19	265	<0.10
213-63	Plating	Cr	Open	push/pull	0.32	389	0.26
213-68	Plating	Cr	Open	push/pull	1.1	460	———
213-69	Plating	Cr	Open	push/pull	0.92	458	———
226-74	Casting	SS	Open	gen mech	0.68	345	0.49
226-75	Casting	SS	Open	gen mech	2.4	332	1.7

Table 4.5.3 (Cont.) Personal Air Sampling Data - Shipyard "C"

Sample #	Process	Base/Filler	Type of Space	Ventilation	Cr(VI) Exposure ($\mu g/m^3$)	Sampling Time/min	OSHA Method 215 8-hr TWA Cr(VI) Exposure ($\mu g/m^3$)
226-76	Casting	SS	Open	gen mech	1.8	338	1.5
226-77	Casting	SS	Open	gen mech	2.4	324	———
226-78	Casting	SS	Open	gen mech	2.1	340	1.5
226-79	Casting	SS	Open	gen mech	1.7	250	———
242-98c	Needle Gunning	Cr paint	Encl	Neg	2.3	186	1.8
242-99b	Needle Gunning	Cr paint	Encl	Neg	2.6	137	3.6

Notes: * TWA based on equivalent exposure for an additional period of welding not captured during the sample time. Samples marked by a small letter in the Sample # column indicate samples for same employee, same day.

‡ TWAs are based on an 11-hour work shift

** Includes 45 min of carbon arcing on same material.

Table 4.5.4 Ranges Of All Shipyard Hexavalent Chromium Worker Exposure Data
Measurements were made using OSHA Method 215 and are presented as 8-hour Time-weighted-averages

Operation/Process/Material	Worker Exposure (μg/m³)							General Area Sample (μg/m³)			
	Total	Open shop/ship/ outdoors		Enclosed shop/ship		Confined shop/ship		Number of Samples	Open	Enclosed	Confined
	Number of Samples	NC	LEV	NC	LEV	NC	LEV		NC/LEV	NC	NC/LEV
Shielded Metal Arc Welding											
SMAW of HY80 and HY100 steels	24	0.4 - 2.2		0.1 - 1.4	0.8		0.7	6	0.1 - 1.6	1.4	
SMAW of Nickel Alloys 600 and 625	5	1.8 - 58			0.2			1	5.4		
SMAW of Stainless Steel (CRES)	24	0.4 - 34	0.1 - 40		11 - 54						
SMAW of Steel	1			<0.1							
Gas Metal Arc Welding											
GMAW of HY80 and HY100 steels	21			0.1 - 0.3	<0.1		<0.11				
GMAW of Nickel Alloys 600 and 625	21	0.3		0.2 - 2			1.2 - 2.2	4		0.02 - 0.06	
GMAW of Stainless Steel (CRES)	1	0.7									
GMAW of High-strength steel (HTS)	2			<0.1			0.1	2			<0.2
Gas Tungsten Arc Welding											
GTAW of HY80 and HY100 steels	1			<0.1							
GTAW of Nickel Alloys 600 and 625	3			<0.1							
GTAW of Stainless Steel (CRES)	16	<0.1-0.2		<0.1-0.4	0.1-0.17			3	<0.1	<0.1	
GTAW of CuNi	2	0.11		<0.1							
GTAW of NiCu	1	<0.2									

NC-No Controls
LEV-Local Exhaust Ventilation

Table 4.5.4 (Cont.) Ranges Of All Shipyard Hexavalent Chromium Worker Exposure Data
Measurements were made using OSHA Method 215 and are presented as 8-hour Time-weighted-averages

Operation/Process/Material	Worker Exposure (µg/m³)							General Area Sample (µg/m³)			
	Total	Open shop/ship/ outdoors		Enclosed shop/ship		Confined shop/ship		Number of Samples	Open	Enclosed	Confined
	Number of Samples	NC	LEV	NC	LEV	NC	LEV		NC/LEV	NC/LEV	NC/LEV
Submerged Arc Welding											
SAW of HY80 and HY100 steels											
SAW of Nickel Alloys 600 and 625											
SAW of Stainless Steel (CRES)	1	<0.1									
SAW of NiCu	1	<0.1									
Grinding of HY80 and HY100	3			<0.1-0.2							
Grinding of Stainless Steel	3	0.29-0.57									
Air Carbon Arc Cutting (CAC-A) of HY80	1				0.21						
Air Carbon Arc Cutting (CAC-A) of Cr Painted Steel	1				13						
Chrome Eletro-Plating	1		0.26								
Stainless Steel Casting	4	0.49-1.7									
Oxy-Fuel Cutting of HY80	2			0.1-0.3							
Oxy-Fuel Cutting Painted Steel	2	9.1			0.7						
Needle Gunning Cr Painted Steel	2				1.8-3.6						

NC-No Controls
LEV-Local Exhaust Ventilation

Table 4.5.5 Ranges Of All Nickel, Manganese and Total Chromium Worker Exposure Data
General Ventilation was Used Unless Otherwise Noted
Measurements were made using NIOSH Method 7300 and are
presented as 8-hour Time-weighted-averages

Operation/Process/Material	Worker Exposure (μg/m³)						
		Open shop/ship/outdoors			Enclosed shop/ship		
	Total Number of Samples	Ni	Mn	Cr	Ni	Mn	Cr
Shielded Metal Arc Welding							
SMAW of HY80 and HY100 steels	4	2.2-4.7	3.5-66	0.9-2.1	5	10	1
SMAW of HY80 and HY100 steels	1				2.6*	52*	1.3*
SMAW of Nickel Alloys 600 and 625	5	2.5-57	1.9-122	2-32			
SMAW of Stainless Steel (CRES)	4	0.7-5.2	3.9-47	0.2-34			
SMAW of Ni-Cu	1	65	45	0.8			
SMAW of Cu-Ni	1	7.8	6.9	1.3			
Gas Metal Arc Welding							
GMAW of Nickel Alloys 600 and 625	23	0.8-98.5	1.2-14	1.2-24.2	15-1290	0.5-150	40-380
GMAW of Stainless Steel (CRES)	1	10.4	16.6	16.6			
GMAW of Cu-Ni	1	7.6	3.6	0.7			
GMAW of Ni-Cu	1	42.2	12.7	2.3			
Gas Tungsten Arc Welding							
GTAW of Nickel Alloys 600 and 625	3				0.8-3.6	1.2-14	1.2-2.6
GTAW of Stainless Steel (CRES)	3	1.8	29	4.6	0.5-1.5	2.7-9.4	0.6-1.2
GTAW of Stainless Steel (CRES)	2	<0.2*	<0.2*	<0.2*	1.1*	9.9*	0.5*
GTAW of Cu-Ni	1				2.9	13.2	6.3
GTAW of Ni-Cu	1				0.4	1.9	0.3
Submerged Arc Welding							
SAW of HY80 and HY100 steels	1	1.6	3.4	0.8			
SAW of Nickel Alloys 600 and 625	1	1	1.1	0.5			
SAW of Stainless Steel (CRES)	1	0.8	1.3	0.3			
Grinding of HY80 and HY100	1	5.2	13.7	2			
Oxy-Fuel Cutting of HY80		15-60	5.4-7.4	1.9-9.3			

* Local Exhaust Ventilation Used For These Tests.

4.6 Summary of Waker Exposue Data

This section provides a summary of the exposure data gathered from published literature, the NEHC database, controlled laboratorey measurements, and worker sampling at shipyards. Only a few of the shipyard and laboratory tests showed levels of Ni above the anticipated new exposure limits. A single laboratory test exceeded the anticipated Mn limit and none of the shipyard or laboratory tests exceeded the current limit for Cr. The data identify a number of conditions that may produce potential exposure to Cr(Vl) that are above the anticipated new exposure limits. The data can be summarized as follows:

Workers in Navy facilities, Navy shipyards, and in the shipbuilding industry who perform the following operations have the highest potential exposure to Ni, Mn, total Cr, and Cr(VI): Metal Cleaning (includes abrasive blasting, grinding, and chipping of coated materials); Electroplating (of chromium); Painting and Coating involving chromates; Casting of chromium containing materials Welding Thermal Spraying; Thermal Cutting; Gouging and Services.

Published literature shows that SMAW and SMAW of stainless and nickel alloys, have the potential to produce worker exposures to Ni and Mn, that may exceed the anticipated new exposure limits. SMAW and GMAW of carbon steels, low alloy steels, and stainless steels also may exceed the new limit for Mn. While few shipyards and laboratory exposure samples exceed the new and anticipated limits, there may other operations (particularly those at high production rates or in enclosed and confined spaces) that were not sampled that have the potential for worker exposures above these limits.

Shipyard data show that exposure levels to Cr(Vl) for welders perfoming SMAW of stainless steel and high-chromium, nickel alloys may be above 5 µg/ti either with or without use of local exhaust ventilation.

Exposure levels to Cr(Vl) for shipyard workers in areas where SMAWis being performed on stainless steel and high-chromium, nickel alloys also may be up to 5 $\mu g/m^3$.

Shipyard data show welders performing GMAW of high-chromium, nickel alloys may be exposed to Cr(VI) in excess of 2 $\mu g/m^3$ and ithout use of local exhaust ventilation, Laboratory tests show the potential exists for even higher exposures during GMAW of stainless steels.

Exposure levels to Cr(Vl) for shipyard welders performing SMAW of HY80 and HY100 low-alloy steels were, in some cases as high as 2 $\mu g/m^3$.

Exposure levels to Cr(Vl) for shipyard welders performing GMAW of HY80 and HY100 low-alloy steels are above 0.25 $\mu g/m^3$ without use of local exhaust ventilation.

Exposure levels to Cr(Vl) for shipyard welders performing GTAW of stainless steels and high chromium nickel alloys are above 0.25 $\mu g/m^3$ without use of local exhaust ventilation.

Local exhaust ventilation was not shown to be effective in reducing welder exposure to Cr(VI) to below 0.5 $\mu g/m^3$ for SMAW and GMAW welding processes when welding on high chromium nickel alloys or stainless steels. Shipyard data indicate local exhaust ventilation did not reduce Cr(Vl) exposure to 5 $\mu g/m^3$ for SMAW of these materials. In addition, no data were found that demonstrate local exhaust ventilation wiIl be completely effective in reducing worker exposure for thermal cutting, gouging, and grinding operations.

Shipyard worker exposure data indicate that SMAW and GMAW of stainless steels and nickel alloys have the highest potential exposure to Ni. Shipyard worker exposure levels to Ni during GMAW of high-chromium, nickel alloys in endosed spaces ranged from 15 $\mu g/m^3$ to over 1 mg/m^3. Over 50 percent of these samples exceeded the anticipated limit of 100 μg/m^3. Welding with these processes in open spaces also has the potential for exposure above 100 μg/m^3, although none of the samples in this study exceeded this value.

Shipyard and laboratory worker exposure data indicate that SMAW and GMAW of stainless steels, carbon steels, and Iow-alloy steels (including HY80 and HY100) have the highest potential for Mn exposure.

Although worker exposures were not measured for the FCAW process, exposures would be expected to similar to SMAW. Further sampling is needed for FCAW.

5.0 CONTROL OF ARB0RNE EMISSIONS

This section of the report discusses some of the currently available methods for control of worker exposure to nickel (Ni), manganese (Mn), chrom"um (Cr), and hexavalent chromium (Cr(VI)) airborne emissions. Engineering controls for airborne emissions include elimination of elements that produce the emissions, modifying the processes to eliminate production of airborne emissions, and use of ventilation to dilute or capture the hazardous materials. These options are discussed below, With emphasis on ventilation for control of Ni and **Cr(VI)** from processes and operations that have been shown to have the potential for exposure to these emissions. Data presented earlier in this report showed that the available ventilation technology cannot be relied on to reduce exposure levels to Cr(VI) below 0.5 $\mu g/m^3$ for many of the welding operations used by the Navy and by the shipbuilding industry. Therefore, it is anticipated that respirator will have to be used in addition to the state-of-the-art controls described here for those operations and processes where Cr(VI) exposure is anticipated.

5.1 Reduction of Nickel and Hexavalent Chromium Emissions Time Material and Process Selection

One option to reduce worker exposure is the selection of base materials and welding consumables that do not contain or produce Ni and Cr(VI) airborne emissions. This option has already been explored for some processes and materials and more studies wiIl be conducted in the future. At this time, it is not possible to say how successful material substitutions will be to eliminate Ni and Cr(Vl) for shipbuilding applications. Section 3 shows that a wide range of materials used for shipbuilding contain Ni and Cr and virtually all of these materials also contain Mn. These materials have been developed to meet stringent service requirements for performance of ships, Navy structures, and weapon systems. Alternate materials may not produce the required service performance or may be too costly.

Likewise, changes in manufacturing and repair operations to eliminate the production of Ni and Cr(VI) airborne emissions may not be practical for many situations. For welding operations, processes as GTAW, PAW, and SAW generate lower levels of Ni and C(Vl) than other processes. However, these Iow-fume generation processes do not have the productivity or flexibility required for many applications. Low fume generation welding consumables are not available or do not produce suitable properties for all applications. Alternative plating, coating, cleaning, and painting operations are under study but no non-hexavalent chromium alternatives are presently available for many Navy applications. New processes wiIl require years of development and evaluation prior to being available for use in Navy facilities and shipyards. Furthermore, the development of alternative processes may not always be successful.

Naval Sea Systems Command[1] conducted a study of the effectiveness of vacuum shrouded local exhaust ventilation sanders and needle guns for shipboard removal of paint This program was specifically directed at concerns for lead exposure, however results are applicable to Ni and Cr(Vl) exposures as well. Tests were conducted using sanders and needle guns to remove paint from horizontal and vertical surfaces aboard five Navy ships. Results showed a 6-fold reduction in the airborne lead levels using the vacuum shrouded tools. However, the tools did not reduce lead levels below the PEL for all situations and particularly not during an entire 8-hour work period. Extrapolation of these results to removal of chromium matings may indicate that even local exhaust ventilation will not be completely successful in reducing worker exposure to Cr(Vl) to the anticipated new Iimits.

1 Final Report Test and Evaluation of Environmentally Acceptable Surface Preparation Equipment Aboard U.S. Navy Ships, Prepared for NAVSEA by: Ocean City Research Corp., Arlington, VA May, *1995*

5.2 Ventilation

General ventilation is a broad term that usually applies to ventilation for comfort control in an office building or non-industrial area. In an industrial setting, it refers to dilution or heat control ventilation. Dilution ventilation may control low concentrations of airborne contaminants such as vapors, gases and particulate at low toxicity. The contaminated air is mixed with dean air to reduce the concentration of potential airborne health hazards and nuisance type fumes, dust or mist Ventilation for heat control reduces the temperature in a hot area by adding "cooler' air to the area.

Dilution ventilation is not used as much as local exhaust ventilation in industrial facilities because of the follwing limitations:

1. The quantity of air contaminants must be fairly low,
2. Emissions must not occur dose to the breathing zone of the worker,
3. Emission sources must not contain highly toxic substances,
4. Evolution or emissions must be uniform over time.

Local exhaust systems are designed to capture and remove process emissions prior to their escape into the workplace environment Local exhaust ventilation is the most effective engineering control for most industrial operations. Local exhaust ventilation uses completely or partially enclosed hoods and booths to capture contaminants. Proper hood or booth designs are critical to the success of local exhaust ventilation system.

The exhausted air is replaced by a supply or replacemmt air system. Improper design of supply or replacement air impairs the effectiveness of the local exhaust ventilation. The replacement air system, therefore also is an important factor of the industrial ventilation system. The amount and the distribution of air are equally important parameters in designing both the industrial exhaust and replacement air systems.

Energy cost reduction is an important design consideration for industrial ventilation processes especially in the cooler parts of the country. Engineers recognize recirculation of exhausted air as an excellent source of cost savings. *The Navy does not recommend* recirculation for most processes requiring industrial ventilation because of requirements for stringent monitoring and feedback control systems. Futhermore, the Navy does not allow recirculation system where lead is expected in the exhaust stream. We anticipate similar problems with hexavalent chromium.

Many temporary operations such as paint removal and painting inside ships require long lines of flexible duct work for supply and exhaust air systems. Limited openings in the ship allow the duct work to pass to the lower decks. However, there are often insufficient openings when extensive work is performed. The resistance developed in the long lines reduces the ability of the portable fan to provide sufficient fresh air or exhaust air to remove the contaminants. Expedience shows that it is difficult to reduce occupation exposures to a level below the current PEL for lead during these motions without the use of respirators.

5.2.1 Common Current Engineering Control Methods for Plating, Spray Painting Blasting and Welding Processes and Their Limitations.

A Plating 0SHA 29 CFR 1910.1000 defines permissible exposure limits for contaminants found in plating shops. OSHA 29 CFR 1910.1000 *also* requires that engineering controls (i.e., local exhaust ventilation) be implemented whenever feasible.

OSHA further regulates open surface tanks under Title 29, Code of Federal Regulations, Part 1910.94 (d). OSHA 29 CFR 1910.94(d)(8) requires baseline and periodic testing. Navy Occupational Safety and Health Program Manual, OPNVINST 5100.23D, Chapter 5, requires ventilation systems to meet or exceed those design standards stated in <u>industrial Ventilation. A Manual of Recommended Practice</u>, by the American

Conference of Governmental Industrial Hygienists (ACGIH) and Military Handbook 1003/17, Industrial Ventilation Systems.

Ventilation rates for chromium plating, cleaning and other operations depends on tank configuration, Iocation, and type of ventilation system. There are three typical lateral exhaust hood designs for controlling the hexavalent chromic add must above the plating tank Figure 5.21 shows these three typical exhaust hood designs.

1. Push-Pull Heeds A nozzle pushes a jet of air across the vessel surface into an exhaust hood. This type of exhaust hood design typically requires 75 cfm/ft^2 or more (Liquid temperature (T) less than or equal to 150° F) of exhaust air, depending on tank temperature ($Q_e = 0.4T + 15 cfm/ft^2$ for T >150°F). The principal advantage of the push-pull over a pull-pull **system** is the reduced exhaust air volume. Its success solely depends on the air-envelope created by the push air nozzle. The pushpull hood design is susceptible to failures due to excess push-air causing turbulence and hanging pants or other obstructions above the liquid surface.

2. PuII-Pull Hoods Air is exhausted through two slotted hoods located on both sides of the plating tank The principal advantage of the pull-pull design is that the capture zone for each hood is only half of the tank width. Hanging parts or obstructions above the liquid surface do not affect hood capture as much with the pull-pull hood. However, the pull-pull hood design requires a greater volume of air than a push pull hood.

3. Pull-Hoods: Air is exhausted through a slotted hood located on one side of the tank The principal advantage of the pull hood design is that it requires less capital cost in duct work and hood construction. In general, this hood design requires the same volume of air as with a pull-pull hood design. It is not as effective as the pull-pull hood design since the single hood has to capture the contaminant over the entire tank width. this type of hood design should be used only for small tank (< 3ft wide).

The three hood designs described above can be designed with side and/or top baffies to reduce crossdraft Hoods with top or side baffles also require less exhaust air.

B. Spray Painting The Navy uses ventilated spray booths and spray rooms to control explosion hazards and to reduce the worker exposure to health hazards in paint spray operations. They function by directing relatively uncontaminated air past the worker towards the process, and into a collection point or exhaust hood. Spray booths range in size from small bench type units to large walk-in units and have one open face. Spray rooms are fully endosed spray areas into which the operator can walk Spray rooms can be large enough to endose an airplane.

For practical purposes, spray booths and rooms can be classified into two basic designs based on the direction of airflow. Booths and rooms with a horizontal airflow are termed “sidedraft", sometimes called crossdraft. Booths and rooms with a vertical airflow are termed "downdraft". Downdraft designs generally provide greater protection, while allowing more freedom of movement for the painter. The disadvantage of a downdraft room is that dead air spaces can be formed around the underside of the objects being painted.

OPNAVINST 5100.23D, Chapter 5, requires ventilation systems of spray paint operation to meet or exceed the design standards set forth in Industrial Ventilation. A Manual of Recommended Practice. by the American Conference of Governmental Industrial Hygienists and Military Handbook 1003/17B, *Industrial Ventilation Systems.*

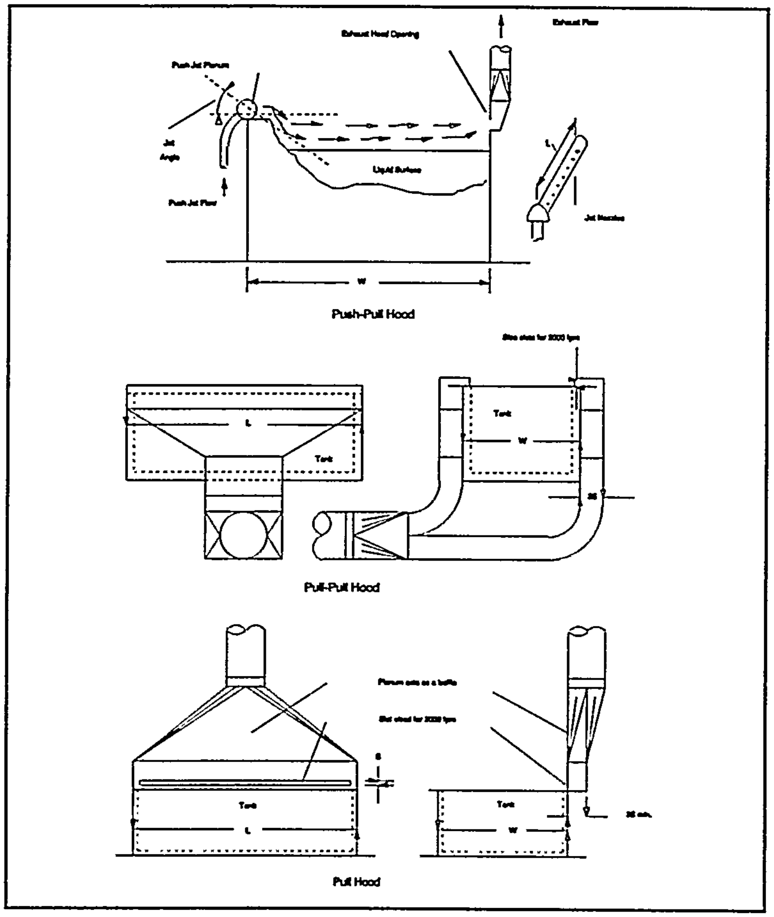

Figure 5.2.1 Typical Exhaust Hood Designs Plating Shop

In the absence of Navy instructions, OPNAVINST 5100.23D, Chapter 16, states Navy cccupational safety and health standards shall also met nationally recognized sources of occupational safety and health guidance. Therefore, Navy paaint booths must also conform to the requirenmts outlined in

- Title 29, Code of Federal Regulations (CFR), Part 1910.94(c), Spary Finishing Operation,
- 29 CFR 1910.107, Spray Finishing Using Flammable and Combusible Materials,
- 29 CFR 1910.1000, Air Contaminants,
- National Fire Protection Association (NFPA) Standard 33, Spray Application Using F/ammble and Combustible Materia/s,
- NFPA Standard 91, Exhaust Systems for Air Converting of Materials,
- American National Standard Institute (ANSI) Standard Z9.2, Fundmentals Governing the Design and Operation of Local Exhaust Systems, and
- ANSI Z9.3 - Design, Construction and Ventilation of Spray Finishing Operations.

The above list does not address design standards that regulate other aspects of painting operations.

To reduce and control volatile Organic compound (VOC) emissions, many states require that paint spraying equlpment transfer efficiencies greater than 65%. To comply, many Navy activities have purchased high-volume low-pressure (HWP) spraying equipment. The HVLP equipment has transfer efficiencies between 65% and 90%.

C. Blasting The Navy removes paint from ships and aircraft and other metal parts either using chemical strippers or abrasive blasting technologies. Chemical stripping is one of the most effective paint removal methods, but it generates a large volume of waste solvent and wash water. These represent a major waste handling and disposal concern for the Navy. Redducing the volume of hazardous chemical waste generated by the Navy has been mandated by the Chief of Naval Operations (CNO) in conformance with Resource Conservation and Recovery and (RCRA) guidance. Chemical stipping also introduces a considerable occupational health exposure. Consequently, the Navy has inplemented several abrasive blasting technologies as dry paint removal techniques.

Traditionally, the Navy used agricultural abrasives (rice hulls, mm cobs, walnut shells, etc), glass beads or metallic abrasives (steel, iron, aluminum oxide, etc) as primary blasting media. Currently, the Navy uses recyclable media, such as plastic in a plastic media blatsing (PMB) system to further reduce the hazardous waste. A PMB system significantly reduces hazardous chemical waste volumes by recycling its blating media and generating only secondary waste (small amounts of paity paint and spent media).

During abrasive blasting operations, workers apply abrasives to a surface by pneumatic pressure, hydraulic pressure or centrifugal force. This shatters and pulverizes abrasives, paint, and base materials either chemically or physically attached to the blasted material to varying degrees. The dust formed may contain a significant number of particles of respirable size (0 to 10 micrometers). The composition and toxicity of such dust often create a health hazard.

OSHA requires an industrial ventilation system where abrasive blasting operations are performed in an enclosure. The industrial ventilation system for abrasive blasting operations used in the Navy must conform to the following regulations and guidance

1. Occupational Safety and Health Administration (OSHA) regulation, 29 CFR 1910.94(a), General Industry Standards govorning abrasive blasting ventilation systems,

2. American National Standard, ANSI Z9.2, F<u>undamentals Governing the Design and Operation of Local Exhaust Systems,</u>

3. American National Standard, ANSl Z9.4, <u>Abrasive Blasting Operations - Ventiatiom and Safe</u> Practices.

4. <u>Navy Occupational Safety and Heath Program Manual</u>, OPNAVINST 5100.23D,

5. American Conference of Governmental Industrial Hygienists (ACGIH) manual, <u>Industrial Ventilation,</u> A Manual of Recommended Practice, and

6. Military Handbook - 1003/17B, <u>industrial Ventilation Systems.</u>

The industrial ventilation system for abrasive blasting operations is primarily designed to increase operator visibility and to prevent exposions resulting from accumulated dust It is not designed to protect operators from respirator hazards generated by heavy dust concentration. Howwer, the presence of a ventilation system can reduce the protection factor needed for respiratory protection. 29 CFR 1910.94(a)(5) decribes the respiratory protecion equipment required in abrasive blasting facilities. When performing work inside a blesting enclosure, the operator must wear a continuous flow, airline respirator that covers head, neck, and shoulders.

D. Welding The Navy designers use Military Handbook 1003/17B which gives general criteria applied to welding operations. ANSI Standard Z49.1-1966 provides additional design criteria for welding operations. in most welting operations, industrial ventilation is provided to reduce exposures to times and particulates. The ACGIH manual, Ind<u>ustrial Ventila</u>tion, A Manual of Recommended Practice, Section

10.90.1 gives the following general recommendations for choosing a ventilation system for welding operations

1. Choose hood designs in the follows descending order of effectiveness enclosing hoods, vacuum nozzles, fixed slot/plenum hood on a worktable or rectangular hood fixed above a worktable, movable hood above a worktable, movable hood hanging freely or overhead canopy, dilution ventilation.

2. Integrate planning for ventilation systems with planning for material handling.

3. Place welding curtain or other barriers to block cross-drafts.

4. Install turntables, work rests and other aids to improve utilization of the hood.

5. Avoid recirculating filtered air from welding hoods back into occupied spaces unless the welding is low hazard and produces low quantities of gaseous contaminants. [Note: *Recirculating systems are never recommended for Navy operations.]*

6. Face velocity for enclosing hoods should be 103-130 fpm with higher values for poor renditions such as high cross-draft velocities.

7. Capture velocities for non enclosing hoods should be 100-170 fpm with higher values used for poor conditions such as cress-draft velocities and with higher hazard levels."

Table 5.21 lists welding hood ventilation solutions (W) given as concept designs in the ACGIH manual, Industrial Ventilation, A Manual of Practice

The advantage of a stationary hood such as a welding bench ventilation hood, is that the hood can be designed to enclose the process as much as possible, thus it can capture most if not all the fume generated by the welding process. The diadvantage of a Stationary hood is that it is not very adaptable to processes for which it was not designed, resulting in possible incomplete capture of the weld fume.

Table 5.21 Welding Hood Drawings

VS Drawing	Drawing Title	VS Drawing	Drawing Title
VS-90-01	Welding Bench Ventilation Hood	VS-90-02	Welding Ventilation - Movable Exhaust Hoods
VS-90-03	Production Line Welding Booth	VS-90-10	Torch Cutting Ventilation
VS-90-20	Robotic Applications	VS-90-30	Metal Spraying

The portable heed (elephant trunk) design uses flexible duct The main advantage of this design is that the hood is and can be positioned close welding operation. The disadvantages of the portable hoods, include the following:

1. The small hood opening does not cover the entire work piece.

2. The operators do not always Properly position the hood.

5.2.2 Status Current Technology

It is impossible to quantify or to predict the worker exposure exclusively on ventilation system design due to the variations in products and processes used in the Navy facilities and shipyards. Most of Navy operations involve repair and maintenance, thus the size and configuration of the products varies from day today. Many innovative processes used in the manufacturing industry (such as robotics) cannot be widely used by the Navy and the shipbuilding industry due to the varying size of the workpieces.

The effectiveness of current engineering control technology has to be evaluated on the case by case basis to see whether it can provide protection for the worker exposure level below the anticipated PEL Industrial ventilation is a technology based on empirical data and experience. Research institutions are only recently quantifying the relationship betveen hood design data and occupational health exposures.

In a study of painting operations by the National Institute for Occupational Safety and Health (NIOSH)[2] it was stated that at a time-weighted-average (TWA) level of 1µg/m^3 "...can only be met by eliminating Cr(Vl) from the coating formulation, or by automating the process and removing the painter." Automation is not feasible for many operations.

A telephone survey of approximately 15 manufactures of ventilation and/or welding equipment revealed no new technologies being developed other than smoke extractor guns. In most cases, the representatives contacted did not know of the anticipated rulemaking for Cr(Vl). One extractor gun manufacture claimed 90% to 98% of the time is removed (this claim was based on visual testing only).

5.2.3 New Technologies Currently Under Field Use Test And Evaluation

The Navy has developed an extensive Pollution Prevention (P2) Program and has compiled "off the shelf' technologies into a Pollution Prevention Opportunity Handbook. Technologies that reduce environmental exposure often have the added benefit of reducing occupational exposure to a contaminant. The Navy does not have information correlating occupational exposures with these technologies at this time. Several technologies reduce or eliminate chromium but introduce other occupational safety and health hazards.

Future research and development programs also are to mininize Ni, Mn, Cr, and Cr(Vl) hazards during fibrication and repair at Navy facilities, and public and private shipyards. This program should address the following areas

- Evaluation of less hazardous base and filler materials
- Evaluation of alternative processes
- Evacuation of improved engineering controls
- Preparation of new requirerments for shipyard use of these hazardous materials
- Expanded use of automation/robotics to reduce exposure
- Design requirements to minimize use of hazardous materials and maximize automation.

[2] NIOSH Publication PB82-162264, An Evaluation of Engineering Control Technology for Spray Painting, June 1981.

6.0 TECHNICAL IMPACT OF THE ANTICIPATED HEXAVALENT CHROMIUM STANDARD

The shipyard worker exposure data in Section 4 show that with a few exceptions, the anticipated OSHA reductions in possible exposure limits **(PEL's)** for hexavalent chromium (Cr(Vl)) are expected to have the largest impact on Navy facilities, public shipyards, and private shipyards. The data show that exposure to nickel (Ni) and manganese (Mn) till impact fewer processes and operations, even at the lower exposure limits.

The recent and anticipated reduction in Ni, Mn, and Cr(Vl) worker exposure limits will have both technical and economic impacts on Navy facilities and public and private shipyards. Econonic impacts of the anticipated Cr(Vl) standard are addressed in the next section of this report. Limitations of present techology to achieve the anticipated OSHA PEL's for Cr(Vl) and the technical impact of these anticipated PEL's on operations in Navy facilities, public shipyards, and private shipyards are discussed here. Future studies will define the technical and economic impacts of the recent change in Mn TLV® and the anticipated change in Ni TLV®. These studies till be reported when they are completed.

Technical impact of the anticipated Cr(VI) standard is anticipated in the following areas

1. Establishment of regulated areas.
2. Effectiveness of engineering controls to reduce Cr(Vl) exposure to the required levels
    - Capability of current technology to meet the anticipated requirements.
    - Ability to change materials or processes.
3. increased use of personal protive equipment including respirators.
4. Housekeeping practices.
5. Criteria for requiring worker training.

6.1 Establishment of Related Areas

The requirement to establish regulated areas for operations where "Cr(Vl) exposure can reasonably be expected to be in excess of the PEL" will mean that a large number of regulated areas till have to be established in shops and on board ships, wherever operations are performed that involve the potential for exposure to Cr(VI). In the case of the early stages of submarine instruction, the entire vessel is likely to become a regulated area for Cr(Vl). This will inpect the scheduling of work and will **result** in reduced efficiency of not only the operations where Cr(Vl) is involved, but adjacent operations and personnel as well. Some of the difficulties with the criteria that trigger the establishment of regulated areas are similar to those discussed below for training (see Section 6.5).

6.2 Effectiveness of Engineering Controls to Reduce Exposure to the Required Levels

Data presented in Sections 4 and 5 of this report show that presently available engineering controls are probably not capable of reducing worker exposure to Cr(Vl) to below the anticipated Cr(VI) PEL's of 0.5 $\mu g/m^3$ or 5.0 $\mu g/m^3$ for a number of operations USA by Navy facilities and public and private shipyards. Local exhaust ventilation is the most effective engineering control presently available for the operations identified with Potential exposure to Cr(Vl). However, ventilation systems used for painting and abrasive blasting processes are not designed to protect operators from respiratory hazards, therefore operators still are required to use respiratory protection. Respiratory protection is currently used in addition to ventilation for metal cleaning, coating, painting, thermal spraying operations and will continue to be required for all anticipated PEL levels.

Published literature, as well as laboratory and shipyard worker exposure measurements, described in Section 4, show that unless very carefully positional, local exhaust ventilation cannot be relied onto reduce exposure to below 5 $\mu g/m^3$ for shielded metal arc welding (SMAVV) of stainless steels or high chromium, nickel alloys. The same problems are projected for the flux cored arc welding (FCAW) process. The data show that local exhaust ventilation is not totally effective in reducing winker exposure to 0.5 $\mu g/m^3$ for gas metal arc welding (GMAW) of stainless steels or high-chromium nickel alloys.

While laboratoy measurements show it is possible to reduce exposure in some cases by careful positioning of local exhaust ventilation, this degree of control will be very difficult in a Navy facility or private shipyard. Workplace limitations, including limited access, may hinder the effective use of local exhaust ventilation in some circumstances. Data are not available to demonstrate that local exhaust will be completely effective for thermal cutting, gouging, and grinding operations. Therefore, without data to show the effectiveness of local exhaust ventilation for the operations under study, the conclusion is that respiratory protection will still be required for these operations in addition to local exhaust ventilation at a PEL of either 0.5 $\mu g/m^3$ or 5.0 $\mu g/m^3$.

Another potential option to reduce exposure levels to Cr(VI) is to eliminate the materials and processes that produce CR(VI). As described in Section 5.1, this option has a number of major technical limitations. Present materials have been developed to meet stringent service requirements for performance of Navy structures and weapon systems. Changes will require extensive development testing and evaluation prior to approval of any new processes and materials. The total technical and economic impact of these changes cannot be estimated at this time.

6.3 Eepected Increased Use of Personal Protective Eqiupment Including Respirators

The use of respiratory protection is likely to increase for two reasons: 1) there will be the need for protection for those operations We workers are exposed over the anticipated Cr(VI) PEL; and 2) there will be the need to augment respiratory protection for those operations where it is presently used based on expected assigned protection factors and selection parameters similar to the cadmium standard (i.e., 29 CFR 1910.1027 or 29 CFR 1915.1027). The anticipated requirements for respiratory protection for Cr(VI), based on the cadmium standard are summarized in Table 6.1.

The limitations of engineering controls to protect workers from exposure to Cr(VI) will greatly expand the use of respiratory protection for workers even with increased use of engineering controls. The current relative use of respiratory protection has been estimated by analyzing the exposure assessments in the Navy Environmental Health Center's Industrial Hygiene Data Capture database. These data are summarized in Table 6.2 This table shows the historical rate of use of respiratory protection and ventilation (or other engineering controls). Respiratory protection is currently used in addition to ventilation for metal cleaning, coating, painting, and thermal spraying operations and will continue to be required for all anticipated PEL levels. The table also shows the percentage of operations conducted in confined or enclosed spaces. The identified use rates were obtained from all Cr(VI) sampling including the 15 minute calling evaluations. Table 6.2 shows that the use of respirators can be expected to increase significantly for operations such as welding due to the anticipated new OSHA PEL standards for Cr(VI) because the present use of respirators for welding operations is relatively low.

The worker exposure data presented earlier in this report were used to generate anticipated Cr(VI) exposure levels as multiples of three possible PEL's: 0.5 μg/m^3, 5.0μg/m^3, and 10μg/m^3. Table 6.3 shows the anticipated exposures as multiples of these PEL's for the operations of interest. This table shows the operations where increased use of respiratory protection, in addition to engineering controls, and other provisions can be expected. Some operations, such as abrasive metal cleaning will require special respiratory protection devices. Each Navy activity and shipyard must select the appropriate respiratory protection based on local worksite exposure evaluations, and Navy and OSHA requirements.

6.4 Housekeeping Practices

The technical feasibility of maintaining work areas "as free as practicable of accumulations of Cr(VI)" places undefined requirements on the facility that must implement this requirement.

6.5 Criteria for Requiring Worker Training

One of the most significant potential technical impacts of the anticipated Cr(VI) standard involves the criterion that will trigger the requirement to provide employee training and information. Agent specific standards such as the General Industry Lead standard and the cadmium standard do not contain uniform criteria. The lead standard mandates training at or above the action level whereas the cadmium standard requires training for workers who are "potentially exposed" to cadmium. The lead standard contains a quantitative criterion; the cadmium standard has a qualitative or subjective criteria. The difficulty with the qualitative criteria lies in defining workers who are "potentially exposed." This is particularly difficult in a shipyard or in construction work where the work environment changes on a day-to-day basis, and it is not practical to identify workers who would satisfy a qualitative criterion.

OSHA has suggested that the trigger for employee training and information in the Cr(VI) standard will be the presence of Cr(VI) in the materials to be worked at a concentration of 0.1% or more. The 0.1% threshold is consistent with OSHA's hazard communication standard which requires the identification of carcinogenic materials on MSDS's when present at concentrations of 0.1% or greater. This criterion may be appropriate and practical for materials such as chromic acid and chromate containing paints but is not appropriate and certainly not practical for materials such as steel plate and consumable welding electrodes that do not contain Cr(VI) compounds. The processing of these materials, however, may cause the generation of Cr(VI) compounds. Consequently, employee training and information would not be required under this criterion when processing steel plate or welding electrodes although it is distinctly possible that detectable levels of Cr(VI) in the air could be generated.

As discussed earlier, the identification and management of "potentially exposed" workers is difficult for cadmium in the construction and shipyard industries because of the inherent nature of the work. It would be exponentially more difficult for Cr(VI) because of the ubiquitousness of metal processing operations in these industries.

Since on any given day, any production worker in the identified operations, including engineering and support personnel, may be "potentially exposed" to Cr(VI) from a compliance perspective, training the entire potentially affected workforce would be the only means to ensure full compliance. The need to train large numbers of personnel will reduce the efficiency of operations and require substantial resources. Costs for these inefficiencies and training are estimated in the next section of the report.

Table 6.1 Anticipated Respiratory Protection Requirements for Cr(VI)
Based on: Respiratory Protection For Cadmium
(29 CFR CH XVII, 1910 . 1027)

Airborne Concentration or Condition of Use[a]	Required Respirator Type[b]
10 x or less	A half mask, air-purifying respirator equipped with a HEPA[c] filter.[d]
25 x or less	A powered air-purifying respiratory ("PAPR") with a loose-fitting hood or helmet equipped with a HEPA filter, or a supplied-air respirator with a loose-fitting hood or helmet facepiece operated in the continuous flow mode.
50 x or less	A full facepiece air-purifying respirator equipped with a HEPA filter, or a powered air-purifying respirator with a tight-fitting half mask equipped with a HEPA filter, or a supplied air respirator with a tight-fitting half mask operated in the continuous flow mode.
250 x or less	A powered air-purifying respirator with a tight-fitting full facepiece equipped with a HEPA filter, or a supplied-air respirator with a tight-fitting full facepiece operated in the continuous flow mode.
1000 x or less	A supplied-air respirator with half mask or full facepiece operated in the pressure demand or other positive pressure mode.
>1000 x or unknown concentrations	A self-contained breathing apparatus with a full facepiece operated in the pressure demand or other positive pressure mode, or a supplied-air respirator with a full facepiece operated in the pressure demand or other positive pressure mode and equipped with an auxiliary escape type self-contained breathing apparatus operated in the pressure demand mode.
Fire fighting	A self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode.

a Concentrations expressed as multiple of the PEL
b Respirators assigned for higher environmental concentrations may be used at lower exposure levels. Quantitative fit testing is required for all tight-fitting air purifying respirators where airborne concentration of cadmium exceeds 10 times the TWA PEL (10 x 5 µg/m³). A full facepiece respirator is required when eye irritation is experienced.
c HEPA means High Efficiency Particulate Air.
d Fit testing, qualitative or quantitative, is required.

Table 6.2 Identified Use Rates of Selected Factors During Cr(VI) Sampling Navy Occupational Exposure Database 1992- June 1995

All Cr(VI) Samples (including 15 minute ceiling samples)

N	Operation	% RESP	% VENT	% CS
9	CON - Construction, Structural Fabrication, Repair	78	11	0
274	IND-001 - Metal Cleaning (includes abrasive blasting, sanding, grinding, needlegunning, etc.)	81	32	<1
4	MIL - Military Specific Operations(i.e., weapons handling, flight line, shipboard, etc.)	100	0	0
26	IND-002 - Metal Cleaning Chemical	15	23	0
18	IND-004 - Electroplating	28	33	0
262	IND-005 - Painting	93	40	0
24	IND-006 - Coating	58	33	0
86	IND-011 - Welding (Resistance, oxyfuel, laser, electron beam, SMAW, GTAW, FCAW, helpers, firewatch)	12	28	5
5	IND-012 - Thermal Spray (arc, flame, plasma)	100	60	0
39	IND-013 - Cutting (includes thermal and non-thermal)	46	3	0
2	IND-020 - Woodworking (treated lumber)	50	100	0
28	IND-025 - Hazardous Material/Hazardous Waste Handling (includes cleanup of industrial areas)	93	7	0
29	SER - Services (transportation, motor vehicle maintenance, etc.)	41	3	0

Key:

N -	Number of samples
% RESP -	Percent of the samples where respiratory protection was used
% VENT -	Percent of the samples where ventilation or some type of engineering control was used (includes enclosures, booths, local exhausted tools, etc.)
% CS -	Percent of the samples where the worker was in a confined or enclosed space

Table 6.3 Anticipated Requirements for Respiratory Protection
Numbers Represent Anticipated Exposure as a Multiple of the PEL

Engineering Controls are Assumed to be Required in All Cases
Open and Enclosed Shop/Ship

Operation	At PEL		
	10μg/m³	5μg/m³	0.5μg/m³
Construction, Repair, Fabrication of Navy Facilities	N	N	10X
Metal Cleaning, Abrasive (Removal of Coatings)	10X	>10X	100X
Metal Cleaning, Chemical	N	N	10X
Electroplating	N	>10X	25X
Painting	10X	>10X	100X
Coating	N	N	10X
Thermal Spraying Thermal Cutting and Gouging	N	N	10X
Services (Transportation, Motor Vehicle, Maintenance)	N	N	10X
Welding:			
SMAW (Ni/SS)*	10X	>10X	100X
SMAW (HY80/100)**	N	N	10X
GMAW (Ni/SS)	N	N	10X
GMAW (HY80/100)	N	N	N
GTAW (Ni/SS)	N	N	N

KEY: N = No respiratory protection is anticipated
* = (Ni/SS) covers welding with Chromium/Nickel Alloys or Stainless Steels
** = (HY80/100) covers welding with HY80 or HY100.

This discussion supports the following recommendations

1) The use of a 0.1% Cr(VI) threshold in the raw materials to be processed is not appropriate because it is not a good indicator of exposure to Cr(VI).

2) The use of a quantitative criterion to trigger worker training is recommmended.

7.0 ECONONIC IMPACT OF THE ANTICIPATED HEXAVALENT CHROMIUM STANDARD

As pointed out in Section 6, shipyard worker exposure data show that the anticipated reductions in permissible exposure Iimits (PEL's) for hexavalent chromium (Cr(Vl)) are expected to have much greater potential impact on Navy facilities and public and private shipyards than the antixcipated redution in the nickel (Ni) limit and the recent reduuction in the manganese (Mn) Iimit Therefore, the Task Group concentrated on estimates of the economic impact of compliance with the Iower anticipated OSHA PEL's for (Cr(Vl)) at Navy activities and public and private shipyards. These estimates are discussed in this section. The Task Group plans to develop cost estimates for the impact of the recent change in Mn TLW® and the anticipated change in Ni TLW®. These estimates will be reported in the future.

7.1 Economic Impact Analysis

OSHA has indicated the Permissible Exposure Level (PEL) for Cr(Vl) may be between 0.5 µg/m^3 and 5.0 µg/m^3. Therefore, the Task Group evaluated the economic impact of the anticipated Cr(Vl) exposure standard at both of these possible PEL's and at a higher PEL of 10.0 µg/m^3. In summary, economic impact for Cr(VI) was estimated for the following conditions

- PEL of 0.5 µg/m^3 and action level of 0.25 µg/m^3
- PEL of 5.0 µg/m^3 and action level of 25 µg/m^3
- PEL of 10.0 µg/m^3 and action level of 5 µg/m^3

The cost data will show that a PEL of 0.5 µg/m^3 would be very costly to the Navy and the private sector, much more so than a PEL of 5.0 µg/m^3 or 10.0 µg/m^3. The feasibility of compliance with the lowest PEL is complicated because more processes are affected, more direct workers are affected, and more work must be disrupted.

7.2 Costs for Medical Survillance and Exposure Monitoring for Navy Facilities

7.21 Air Monitoring and Re-sampling Costs

Data presented in Section 4 show that most operations lack the number of samples to conclusively determine that exposure to Cr(Vl) above 0.5 µg/m^3 will not occur. Past sampling data (see Table 4.26 and Table 4.27) were used to estimate there-sampling of work operations that will be required to determine compliance to the anticipatd Cr(Vl) PEL Estimates also considered the expected new regulatory requirements for negative assessments, and initial and periodic sampling for Cr(Vl) based on the cadmium standard (29 CFR 1910.1027 and 29 CFR 1926.63). The anticipated Cr(Vl) standard will require the re-evaluation of operations as well. For comparison, the operations that provided an exposure potential to cadmium are similar to the operations providing an exposure potential to Cr(Vl).

There will bean expected increase in sampling for Cr(Vl) due to projected regulatory requirements. Prior to promulgation of the cadmium standards, (29 CFR 1910.1027 and 29 CFR 1926.63), a relatively consistent number of air samples were conducted for cadmium in relation with the total number of personal breathing zone samples. After promulgation, the ratio changed due to the regulatory requirement to perform both initial and periodic sampling:

Ratios Cadmium/Total Personal Breathing Zone Samples

Year	1991	1992	1993	1994
Ratio of Cadmium Samples to Total Personal Breathing Zone Samples	0.01885	0.01927	0.10478	0.09161
Average ratio	before Cd rule 0.01906		after Cd rule 0.0982	

This represents a 515% increase in cadmium personal breathing zone sampling.

Applying this expected ratio to Cr(VI) sampling due to the anticipated rule:

Year	1992	1993	1994	Annual Average
Number of Samples	222	235	240	232

Average 232 x 515% = 1195 Cr(VI) samples per year.

At $50 per Cr(VI) sample (including media):

Current sampling $50 x 232 = $11,600

Projected cost after promulgation of Cr(VI) standard $50 x 1195 = $59,750 per year for sampling. This is an increase of $48,150 per year.

The increase in required work effort and the costs for Navy and contracted services were estimated as follows based on the above average annual increase of 1195 monitoring samples for Cr(VI). Assuming an average of 2 samples can be conducted per evaluation day, and each evaluation day requires a full day of sampling (at least 8 hours), the following work effort is derived:

$$\frac{1195}{2} = 597.5 \text{ worker-days/year} \quad \text{or,}$$

597.5 x 8 hours = 4780 worker-hours/year

Assuming a contract rate for technician level (per *Industrial Safety & Hygiene News* Consultant Survey March 1995) of $50.00/hour, this would relate to,

4780 worker-hours x $50.00 = $239,000/year

The actual number of samples needed will be operation and site specific. Some work areas may require several samples that could be performed in one session. Other remote sites will require multiple days of evaluation. Navy industrial hygiene personnel support is not expected to increase. In fact, down-sizing of all DoD activities is expected to significantly impact industrial hygiene support of Navy workplaces. However, promulgation of a specific standard for Cr(VI) will divert resources from other occupational health concerns further straining personnel. Augmentation of Navy industrial hygiene staff and/or contracting of industrial hygiene services for Navy operations is not expected to occur for the anticipated Cr(VI) standard.

7.2.2 Metal Surveillance Costs

Athough medical surveillance requirements for the anticipatd Cr(VI) standard have not been established, based on a telephone conversation with Dr. Melissa McDiamid, OSHA medical surveillance under a new standard is likely to include blood and urine chromium testing, beta-2-microglobulin measurements (urine) and a clinical evaluation. Current contract laboratory funding requirements for this level of testing is as follows blood chromium ($45-$50 per sample), urine chromium ($41-$44 per sample), and beta-2-microglobulin ($50 per test). The total cost per employee is estimate at $136-$144 per employee. In addition, a workload estimate of 0.25 to 0.33 physician/non-physiaan healthcare provider, 0.10 to 0.25 occupational nurse, and 0.25 occupational health technician worker-houis for each chromium evaluation is not unreasonable.

Given the current "right-sizing" of the DoD, it is unlikely that additional Navy uniformed or civil service healthcare provider positions will be created to meet any increased workload required by a revised chromium standard. Accordingly, it must be presumed that a concomitant restructuring of occupational health personnel priorities, including most probably decreased time allotted to preventive efforts such as health promotion and worksite visits, would occur should any new standard be mandated. The indirect rests incurred by this reduction of emphasis on preventive efforts is difficult to quantify, but could certainly be substantial if significant numbers of Navy employees will require chromium medical surveillance.

7.3 Cost of Hexavalent Chromium Compliance

7.3.1 Primary Cost Analysis Method

The Task Group estimated the number of workers in Navy facilities and in selected private shipyards and small marine businesses who maybe impacted by the anticipated reduction of the OSHA Cr(VI) PEL. These are the workers who perform the operations identified in Section 3 and Section 4 as having potential Cr(Vl) exposure at the three PEL's given in Section 7.1. Table 7.1 shows that over 18,000) workers may be potentially exposed to Cr(Vl) above 0.5 µg/m^3 due to the identified operations. This estimate represents 17 Navy facilities, 5 private shipbuilders (Navy contractors) and 6 smalll marine businesses. One-third of these workers are potentially exposed to welding fumes. An estimated 3,200 workers are potentially exposed to Cr(VI) levels above 5.0 µg/m^3 and over 800 workers above 10.0 µg/m^3. This does not represent the entire population of workers in the shipbuilding industry who may be exposed to Cr(VI) at these levels but does repressent a large portion of affected Navy facilities and a portion of the shipbuilding industry.

The costs of compliance with the anticipated new OSHA Cr(Vl) standard were estimated for the three PEL levels listed in Section 7.1. These costs include one-time costs as well as on-going annual costs of compliance. The Task Group identified the following areas where the anticipated Cr(VI) standard Will impact the cost of Navy facilities and public and private shipyards

Administrative costs:

- Personnd trainning on hazards of exposure to Cr(VI).
- Monitoring for airborne Cr(VI) levels.
- Medical surveillance of exposure of personnel.
- Hygiene facilities for showwring and changing.
- I%tablishmnt and enforcement of regulatd areas.
- Housekeeping and cleaning protective clothing.
- VVW&l compliance programs.

Cost of engineering controls

- Equipment research and development.
- Equipment procurement
- Equipment installation.
- Equipment maintenance.
- Personnel training in the used maintenance of engineering controls.

Cost of clothing and other personnel protective equipment

- Protective clothing including coveralls and gloves.
- Protective foorware.
- Respiratory protection.
- Personnel training in the proper use of protective equipment

Cost impact on productivity

- Loss of worker time due to increased setup time, reduced efficiency, changing clothes and showering, and medical surveillance.
- Increased process or materials cost
- Cost of restricted access areas.
- Schedule delays due to disruption/delays of other operations precluded from restricted access areas, forcing duct of operations in series rather than parallel.

7.3.1.1 Cost Analysis

A bottomup approach was used to estimate the total cost of compliance with the anticipated lower Cr(Vl) PEL's. Cost estimates from Norfolk Naval Shipyard (NNSY) and three private shipyards were projected to cover 17 Naval Activities, 5 private shipyards, and 6 small marine businesses where exposure to Cr(Vl) is expected. All Costs were projected assuming proportionality to the number of affected workers. Table 7.1 shows the Estimated Population of workers Potentially Exposed to Cr(Vl) by operation at three anticipated PEL levels. It is expected that 16% of those who maybe potentially exposed over 0.5 µg/m^{3}would be exposed at over 5.0 µg/m^{3}based on the average percentage difference between the levels estimated by Shipyard #1 and #2 and NNSY. It is further estimated that of those potentially exposed above 5.0 µg/m^3, 16% would be potentially exposed at levels above 10.0 µg/m^3. Tables 7.2,7.3, and 7.4 show the Estimated Cost of Compliance for a PEL of 0.5 µg/m^3, 5.0 µg/m^3, and 10.0 µg/m^{3}respectively.

Nay Activity costs are based on per worker costs at NNSY. Private Shipyard rests are based on an average per worker cost calculated using data from Shipyard #1 and #2. Data Item shipyard #5 was not used in calculating the average costs but were added in separately. Cost for shipyard #5 are necessarily much higher than other shipyards because of the extensive use of materials containing chrome and work in confined spaces in shipyards.

7.3.1.2 Naval Activities

Approximate Total Costs for Naval Activities for PEL of 0.5 µg/m^3:

Currently Exposed Population	13,357 workers
Annual Costs	$46,000,000
One-time costs	$22,000,000

Approximate Total Costs for Naval Activities for PEL of 5.0 µg/m^3:

Currently Exposed Population	
Annual Costs:	$5,000,000
One-time Costs	$3,000,000

Approximate Total Costs for Naval Activities for PEL of 10.0 µg/m^3:

Currently Exposed Population	
Annual Costs	$2,000,000
One-time Costs:	$1,000,000

7.3.1.3 Private Shipyards

Total Costs for Private Shipyards for PEL of 0.5 µg/m^3:

Currentiy Exposed Population	4702 workers
Annual Costs	$37,000,000
One-time Costs:	$9,000,000

Total Costs for Private Shipyards for PEL of 5.0 µg/m^3:

Currently Exposed Population:	1235 workers
Annual Costs:	$12,000,000
one-time Costs:	$2,000,000

Total Costs for Private Shipyards for PEL of 10.0 µg/m^3:

Currently Exposed Population	499 workers
Annual Costs:	$12,000,000
One-time Costs:	$2,000,000

7.3.1.4 Total Cost Data Summar

Total Costs for PEL of 0.5 µg/m^3:

Currently Exposed Population	18,059 workers
Annual Costs:	$83,000,000
One-time Costs:	$31,000,000

Total Costs for PEL of 5.0 µg/m^3:

Currently Exposed Population	3,225 workers
Annual Costs:	$17,000,000
One-time Costs:	$5,000,000

Total Costs for PEL of 10.0 µg/m^3:

Currently Exposed Population	804 workers
Annual Costs	$14,000,000
One-time Costs:	$3,000,000

These data clearly show that the lower PEL (0.5 µg/m^3) carries a much greater cost of compliance. This is primarily because many more workers could be exposed above 0.5 µg/m^3 compared to 5.0 µg/m^3.

7.4 Alternate Hexavalent Chromium Complaince Cost Calculations

7.4.1 Hazardous Material Study

The algorithms of the Hazardous Matetials Life Cycle Estimator, a DOD approved computer model maintained by the Human systems Center at Brooks Air Force Base, Texas, were used to produce an alternate estimate of annual compliance costs. These algorithms were used to estimate the cost of hexavalent chromium compliance. This analysis resulted in an estimated average annual cost per shipyard worker exposed to Cr(VI) of approximately $11,600. This figure indudes:

- Training -$300 per worker (4 hours per worker at $50 per worker-hour plus $100 for course material, etc.)
- Personal protection Equipment (PPE) - $1000 per worker.
- Lost Productivity -$10,000 per worker (1 hour per day for 200 days per year at $50 per worker-hour).
- Medical -$300 per worker ($220 for physical and $80 for Medical Surveillance, Injury and Illness and Industrial Hygiene survey.

The total compliance cost for 18,000 workers using this estimate would be $200 trillion for these items alone. This total does not however, account for several items, the largest of which is the cost of engineering controls.

7.4.2 Prioductivity Impact

Discussions with members of the Task Group revealed that 2 hours of lost productivity per worker per day is a more reasonable figure to expect for compliance to the anticipated new Cr(VI) standard. This includes time lost changing in and out of protective gear and dothing, showering, transport to and from the shower faciliy, lost time for medical testing, increased set up time and working pace due to more cumbersome gear. This figure (25 percent of 8-hour worker productivity) is not fully reflected in the data provided in Section 7.3 and would significantly increase the cost estimate. The amount of increase would depend on the number of working days the worker could posssibly be subjected to a Cr(VI) hazard above the action level. For example 18,000 wokers exposed100 days per year could involve a loss of 3.6 million worker-hours or $180 million per year at a labor rate of $50 per hour. In determining the number of days that workers would bekin the Cr(IV) program, having the work force capable of being assigned for rnaximum productivity and flexibility must be considered. This would significantly increase the number of days in the program

7.5 Cost Summary

Due to the limited time to gather data for this repot, the data here are not all-inclusive. Not included are population or cost data from subcontractors to all public and private activities. Atlantic coast Intermediate Maintenance Activities (IMA) are included in the NAVSURFLANT numbers but Pacific coast IMA population data are not included. When all activities are taken into account, the actual cost is expected to be 50% to 100% higher. Total annual costs could range from $123 to $164 million at a PEL of 0.5 μg/m^3 using the more conservative cost-building method in section 7.3. The figures from section 7.4 indicate that the cost of compliance could be much higher, several hundreds of millions of dollars, if the productivilty loss figures prove to be accurate.

Table 7.1 Estimated Population of Workers Potentially Exposed to Cr(VI)

Activity	Welding	Thermal Cutting	Grinding	Thermal spay	Casting	Plating	Painting	Paint Removal	Metal cleaning	Indirectly Exposed	Over 0.5 µg/m³	Over 5.0 µg/m³	Over 10.0 µg/m³
Private Shipyard #1	1000	100	1000				10	500	30	2470	1000	100	10
Private Shipyard #2	1250	800	800		15	2	6	40			2117	590	165
Private Shipyard #3	140	140	140								140	14	3
Private Shipyard #4	860	860	860								860	86	17
Private Shipyard #5	888	547	697								1300	500	192
Small Marine Bus. #1	6	6	6										
Small Marine Bus. #2	1	1	1								1	0	0
Small Marine Bus. #3	4	4	4								4	1	0
Small Marine Bus. #4	2	2	2								2	0	0
Small Marine Bus. #5	1	1	1										
Small Marine Bus. #6	2	2	2								2	0	0
NSY Norfolk	326	536	579	6	110	12		410	4	475	2458	246	26
NSY Portsmouth	161	176	176				111				448	45	9
NSY Puget Sound	285	652	689			10		258		350	2061	206	41
NSY Long Beach	85	26	26				39			36	186	19	4
NSY Pearl Harbor	71	157	166			2		86		96	538	54	11
NSWC Annapolis	8	8	8										
NSWC Panama City	21	21	63				2				86	9	2
NWS Charleston	4	4	4				5			49	58	6	1
NWS Earle	10		5				5				20	2	0
NWS Yorktown	4	4	4			1	3			5	8	1	0
NWS Dahlgren	10	10	10				5			40	55	6	1
NWS Indian Head	4	4	4				4			8	16	2	0
EOD Tech Div	12	12	14			12	14				52	5	1
NMC Bethesda	11	16	16				2			51	23	2	0
NADEP Cherry Point	26	11	260	9	7	94	97	107	84	26	726	73	15
NADEP North Island	20	20	300	6	4	131	100	110	27	7	725	73	15
NADEP Jacksonville	45	17	450	8	11	100	120	100	77	19	947	95	19
NAVFACENGCOM											1437	144	29
NAVSURFLANT	1200	1200	1200			30	1200	1200	1200	1075	3505	561	90
Navy Total	2303	2874	3974	29	132	392	1707	2271	1392	2191	13357	1990	305
Ship builder Total	3439	1748	2798	0	15	2	16	540	30	2470	4702	1235	499
Grand Total	5742	4622	6772	29	147	394	1723	2811	1422	4611	18059	3225	804

The chart shows workers potentially exosed to Cr(VI) due to the due to the shown processes. A worker exposed due to several processes and will be shown in each applicable column.

Table 7.2 Estimated Cost of Compliance to a PEL of 0.5$\mu g/m^3$

Cost Elements	Annual Cost ($K) for 1000 Workers	One-Time Costs ($K) for 1000 Workers
Cost of Administrative provisions	**802**	205
Cost of Engineering Controls	646	583
Cost of dothing or other PPE	206	163
Cost of resporatory protection	124	23
Cost impact on ship production/repair	1,674	705
Subtotal	3,453	1,679
Projected Navy Costs for 13357	46,118	22,430
Projected Private Shipyard Costs for 3402 workres	11 746	5,713
Special Shipyard Costs for 1300 workers	25,000	000
Projected Grand Total Totall for 18809 workers	82,864	31,143

Table 7.3 Estimated Cost of Compliance to a PEL of 5.0 $\mu g/m^3$

Cost Elements	Annual Cost ($K) tori(x) Workers	One-Time costs($K) For 160 Workers
Cost of Administrative provisions	70	98
Cost of Engineering Controls	27	82
Cost of clothing or Other PPE	21	16
Cost of respiratory protection	*15*	*2*
Cost impact on ship production/repair	282	57
Subtotal	416	255
Projected Navy Costs for 1990 workers	5,168	3,176
Projected Private Shipyard Costs for 735 workers	1,909	1,173
Special Shipyard Costs for 500 workers	10,000	1,000
Projected Grand Total for 3225 workers	17,077	5,350

Table 7.4 Estimated Cost of Compliance to a PEL of $10.0 \mu g/m^3$

Cost Elements	Annual Cost($K)for 32 Workers	One-Time Costs($K) for 32 Workers
cost of Administrative provisions	37	33
Cost of Engineering Controls	33	37
Cost of clothing or other PPE	4	3
Cost of rspiratory protection	3	<1
Cost impact on ship production/repair	139	5
Subtotal	216	79
Projected Navy Costs for 305 workers	2,067	757
Projected Private Shipyard Costs for 307 workers	2,080	837
Special Shipyard Costs for 192 workers	10,000	1,000
Projected Grand Total for 804 workers	14,147	2,594

7.6 Economic Impact Cost Estimation Details

7.6.1 Data Provided to the Task Group

The following tables show details of population and cost estimate data provided to the Task Group and used to establish the cost estimates described in the previous sections. Table 7.5 shows population data provided from each activity. Tables 7.6 through 7.11 give cost estimates from four activities and the average figures that ware used to compute total costs in Section 7.3.

7.6.2 Method for Calculation of Figures in Table 7.1

The population numbers shown in Table 7.5 are the raw data provided to the Task Group and do not in all cases match the numbers shown in the composite Table 7.1. Several methods were used to translate the raw data into the numbers in Table 7.1:

- For shipbuilders where only a figure for welder population was provided, 20% of those w#ers would be expected to be exposed to Cr(VI) based on figures from shipbuilders #1, #2, #3, and #4. It also was expected that those welders would be exposed during cutting and grinding operations.

  $$\frac{39\%+19\%+20\%+3\%}{4} = 20\%$$

- For the smaller marine businesses, it is expected that fewer welders (10%) will be exposed to Cr(VI) because the use of materials containing chromium is not as prevalent in smaller commercial yards.

- Were it was not specified at which levels workers ware to be exposed, all potentially exposed workers were expected to be exposed above a PEL of 0.5 $\mu g/m^3$ as shown in Table 7.1 in which virtually all operations have the potential for exposure levels greater than 0.5 $\mu g/m^3$.

- Where the number of exposed workers above a PEL of 5.0 $\mu g/m^3$ was not given, it was expected that 16% of those potentially exposed over 0.5 $\mu g/m^3$ would be potentially exposed at over 5.0 $\mu g/m^3$ based on the average percentage differ- between the levels shown in shipbuilder #1 and #2 and NNSY data.

  $$\frac{10\%+28\%+10\%}{3} = 16\%$$

- Where the number of exposed workers above a PEL of 10.0 $\mu g/m^3$ was not given, it was expected that 16% of those potentially exposed over 5.0 $\mu g/m^3$ would be potentially exposed at over 10.0 $\mu g/m^3$ based on the average percentage difference between the levels shown in shipbuilder 1 and 2 and NNSY data.

  $$\frac{10\%+28\%+10\%}{3} = 16\%$$

7.6.3 Method for Determining Total Cast of Compliance

Tables 7.6 through 7.11 show cost estimate data provided to the Task Group, average costs, and total costs of compliance. Although limited data were used, the overall order of magnitude of the figures tends to agree. Much of the data scatter is due to similar items falling under different categories for separate cost estimates. Because of the large cost estimate differential between shipbuilder #5 and the other estimates, figures from shipbuilder #5 were not used in the averaging calculations but were added separately. The cost estimate for shipbuilder #5 is much larger because of extensive use of materials containing chromium and work in confined spaces.

7.6.3.1 Annual Cost Data

Tables 7.6,7.8, and 7.10 show data provided for annual cost estimates for different PEL's. Although costs were, in some cases, separated into annual costs per worker and fixed annual costs, an average annual cost was formed basal on a potentially exposed worker population of 1000 at a PEL of 0.5 μg/m^3. This translates into potentially exposed populations of 160 workers for 5.0 μg/m^3 PEL using the 16% calculated above and 32 workers 10.0 μg/m^3 PEL using the 16% calculated above. The average figure was calculated by adding all fixed annual costs and total annual worker costs for a given category, dividing by the sum of the workers at all of@ activities and multiplying by an exposed population of 1000 at PEL of 0.5 μg/m^3, 160 at PEL of 5.0 μg/m^3, or 32 for a PEL of 10.0 μg/m^3. For example, the Average Annual Cost of Administrative Provisions at a PEL of 0.5 μg/m^3 as shown on the first row of Table 7.6

$$\frac{(\$304 \times 2458 + \$704 \times 1000 + \$811{,}000 + \$409.000 + \$1{,}800{,}000)}{(2458+1000+2117)} \times 1000 = \$802{,}015$$

Total Annual Costs (TAC) were calculated by dividing the Average Total Annual Cost (ATAC) by the total number of exposed workers (TEW):

$$TAC = \frac{ATAC}{1000} \times TEVV$$

(e.g. Total Annual Costs for Navy Activities for PEL 0.5 μg/m^3 in Table 7.6)

$3,452,714x13357=$46,117,900

The cost estimate from shipbuilder #5 was added in separately.

7.6.3.2 One-Time Cost Data

Tables 7.7,7.9, and *7.11 show* cost estimates for one-time start-up costs for compliance for different PEL's. The average figure was calculated by adding all ore-time costs and dividing by the sum of the number of workers at all of the activities and multiplying by an exposed population of 1000 at PEL of 0.5 μg/m^3, 160 at PEL of 5.0 μg/m^3, or 32 for a PEL of 10.0 μg/m^3. For example, the Average Annual Cost of Administrative Provisions at a PEL of 0.5 μg/m^3 as shown on the first row of Table 7.7:

$$\frac{\$325{,}000 + \$654\,()()() + \$165.000}{2458+1000+2117} \times 1000\ \$205{,}202$$

Total One-time Costs (TOC) were calculated by dividing the Average Total One-time Cost (ATOC) by the total number of exposed workers (TEW):

7.6.3.3 Projected Totals

Projected totals were calculated as being proportional to worker populations in Table 7.1. For example, the Projeced Total for Navy Activities at a PEL of 0.5 µg/m^3 as shown on Table 7.7 is

$$\$3,452,714 \text{x } 13357 = \$46,117,900$$

Table 7.5 Estimated Exposed Population Data

Activity	Welding	Thermal Cutting	Grinding	[redacted]
Shipbuilder #1	1000	100	1000	[redacted]
Shipbuilder #2	1250	800		[redacted]
Shipbuilder #3	140			[redacted]
Shipbuilder #4	860			[redacted]
Shipbuilder #5	888	547	697	[redacted]
Small Marine Bus. #1	60			[redacted]
Small Marine Bus. #2	12			[redacted]
Small Marine Bus. #3	42			[redacted]
Small Marine Bus. #4	15			[redacted]
Small Marine Bus. #5	14			[redacted]
Small Marine Bus. #6	15			[redacted]
NSY Norfolk	326	536	579	[redacted]
NSY Portsmouth	161	176		[redacted]
NSY Puget Sound	285	183	508	[redacted]
NSY Long Beach	85	26		[redacted]
NSY Pearl Harbor	71	117	126	[redacted]
NSWC Annapolis	8			[redacted]
NSWC Panama City	21		63	[redacted]
NWS Charleston	4			[redacted]
NWS Earle	10		5	[redacted]
NWS Yorktown	4			[redacted]
NWS Dahlgren	10			[redacted]
NWS Indian Head	4			[redacted]
EOD Tech Div	12		12	[redacted]
NMC Bethesda	11	9		[redacted]
NADEP Cherry Point	26	11	260	[redacted]
NADEP North Island	20	20	300	[redacted]
NADEP Jacksonville	45	17	450	[redacted]
NAVFACENGCOM				[redacted]
NAVSURFLANT	1200	1200		[redacted]

Table 7.7 Estimated Program Startup Cost for PEL of O.5 $\mu g/m^3$

Estimated Program Startup Cost for PEL of 0.5 µg/m3					
Cost Elements	One-Time Cost				Average One-Time Cost
	NNSY	SB#1	SB#2	SB#5	for 1000 workers
Exposed Population	2458	1000	2117	1300	1000
Cost of Administrative provisions	$325,000	$654,000	$165,000		$205,202
Training					
Monitoring					
Medical surveillance					
Housekeeping					
OSHA/EPA management					
Cost of Engineering Controls	$2,748,000		$500,000		$582,601
Development of Procedures					
Ventilation source capture					
Maintenance, service and repair					
Cost of clothing or other PPE	$100,000	$800,000	$8,000		$162,870
Cost of respiratory protection	$40,000	$90,000			$23,318
Respirator cost					
Maintenance					
Cost impact on productivity		$3,332,000	$600,000		$705,291
Total ($K)	$3,213,000	$4,876,000	$1,273,000	$3,000,000	$1,679,283
Projected Totals	One-Time Cost				
'Navy Activity Costs	$22,430,177				
Ship builder	$5,712,919				
Special Ship Builder	$3,000,000				
Total	$31,143,096				

Table 7.8 Estimated Cost of Compliance for PEL of 5.0 µmg/^{3}

Estimated Annual Cost of Compliance for PEL of 5.0 µg/m3									
Cost Elements	Estimated Annual Cost Per Worker				Estimated Fixed Annual Cost				Average Total Annual
	NNSY	SB#1	SB#2	SB#5	NNSY	SB#1	SB#2	SB#5	Cost for 100 workers
Exposed Population	246	100	590	390	246	100	590	390	100
Cost of Administrative provisions	$304	$650			$77,000	$41,000	$400,000		$70,276
Training	$84				$7,000				
Monitoring	$38				$9,000				
Medical surveillance	$162				$40,000				
Housekeeping	$20				$5,000				
OSHA/EPA management					$16,000				
Cost of Engineering Controls					$58,000		$200,000		$27,564
Development of Procedures					$8,000				
Ventilation source capture									
Maintenance, service and repair					$50,000				
Cost of clothing or other PPE	$20	$800			$27,000	$80,000	$2,000		$20,718
Cost of respiratory protection	$36	$175			$93,000	$4,000	$20,000		$15,316
Respirator cost	$16				$66,000				
Maintenance	$20				$27,000				
Cost impact on productivity		$334			$1,470,000	$233,000	$900,000		$281,667
Subtotal	$360	$1,959							
Total ($K)	$88,560	$195,900		$8,500,000	$1,725,000	$358,000	$1,522,000	$1,500,000	$415,541
Projected Totals	Annual Cost								
'Navy Activity Costs	$5,168,286								
Ship builder	$1,908,890								
Special Ship Builder	$10,000,000								
Total	$17,077,176								

[redacted]

Total	$5,349,519				

Table 7.10 Estimated Cost of Compliance for PEL of 10.0 µg/m[3]

Estimated Annual Cost of Compliance for PEL of 10.0 µg/m3									
Cost Elements	Estimated Annual Cost Per Worker				Estimated Fixed Annual Cost				Average Total Annual
	NNSY	SB#1	SB#2	SB#5	NNSY	SB#1	SB#2	SB#5	Cost for 32 workers
Exposed Population	26	10	165	117	26	10	165	117	32
Cost of Administrative provisions	$304	$650			$16,000	$4,000	$200,000		$37,318
Training	$84								
Monitoring	$38								
Medical surveillance	$162								
Housekeeping	$20								
OSHA/EPA management									
Cost of Engineering Controls					$7,000		$200,000		$32,955
Development of Procedures					$2,000				
Ventilation source capture									
Maintenance, service and repair					$5,000				
Cost of clothing or other PPE	$20	$800			$1,000	$8,000	$10,000		$4,381
Cost of respiratory protection	$36	$175			$3,000	$1,000	$10,000		$2,656
Respirator cost	$16				$1,000				
Maintenance	$20				$2,000				
Cost impact on productivity		$334			$350,000	$23,000	$500,000		$139,517
Subtotal	$360	$1,959							
Total ($K)	$9,360	$19,590		$8,500,000	$377,000	$36,000	$920,000	$1,500,000	$216,828
Projected Totals	Annual Cost								
'Navy Activity Costs	$2,066,641								
Ship builder	$2,080,192								
Special Ship Builder	$10,000,000								
Total	$14,146,833								

Table 7.11 Estimated Program Startup Cost for PEL of 10.0 $\mu g/m^3$

Estimated Program Startup Cost for PEL of 10.0 µg/m3					
Cost Elements	One-Time Cost				Average One-Time Cost
	NNSY	SB#1	SB#2	SB#5	for 32 Workers
Exposed Population	26	10	165	117	32
Cost of Administrative provisions	$17,000	$28,000	$165,000		$33,433
Training					
Monitoring	$17,000				
Medical surveillance					
Housekeeping					
OSHA/EPA management					
Cost of Engineering Controls	$35,000		$200,000		$37,413
Development of Procedures	$8,000				
Ventilation source capture	$27,000				
Maintenance, service and repair					
Cost of clothing or other PPE	$10,000	$8,000	$2,000		$3,184
Cost of respiratory protection		$1,000			$159
Respirator cost					
Maintenance					
Cost impact on productivity		$33,000			$5,254
Total ($K)	$62,000	$70,000	$367,000	$1,000,000	$79,443
Projected Totals	One-Time Cost				
Navy Activity Costs	$757,189				
Ship builder	$836,632				
Special Ship Builder	$1,000,000				
Total	$2,593,821				

8.0 CONCLUSIONS

This section of the report presents the conclusions of the Navy/Industry Task Group regarding the new and anticipated OSHA and ACGIH reductions in worker exposure limits for nickel (Ni), manganese (Mn), and hexavalent chromium (Cr(VI)). During this study the Task Group:

- Identified the manufacturing and repair operations, materials, and processes used in Navy facilities, public shipyards, and private shipyards that are expected to be impacted by the new and anticipated reductions in Ni, Mn, and Cr(Vl) exposure limits. The number of workers involved with these operations, materials, and processes also was estimatd for Cr(VI).

- Gathered data on worker exposure to Ni, Mn, total Cr, and Cr(Vl) by:
  Reviewing published literature;
  Reviewing historical data from the Navy Environmental Health Center database;
  Conducting controlled laboratory measurements;
  Sampling worker exposures in three private shipyards.

- Identified the technical and economic impact of the proposed reduction in Cr(Vl) exposure limits on Navy facilities and public and private shipyards.

Task Group findings support the following conclusions

1) Workers in Navy facilities and public and private shipyards who perform the following operations are the most likely to be exposed to Ni, Mn, total Cr, and Cr(Vl):

   - Construction, Structurall Fabrication and Repair of Facilities;
   - Metal Cleaning (includes abrasive blasting, grinding, chipping and acid cleaning);
   - Casting;
   - plating;
   - painting;
   - Coating;
   - Machining
   - Welding;
   - Thermal Spraying;
   - Thermal Cutting and Gouging;
   - Woodworking (of pressure treated wood);
   - Services (includes transportation, motor vehicle, maintenance).

2) The anticipated reduction in the permissible exposure limit (PEL) for hexavalent chromium (Cr(Vl)) is expected to have much greater potential impact on Navy facilities and public and private shipyards than the new and antiapated reductions in nickel (Ni) and manganese (Mn) limits.

3) Exposure to Cr(Vl) can be expected when the operations listed in 1) above are performed on or with materials that contain chromium chromates. This includes chromate paints, coatings, and chromium plating. This also includes thermal processing of stainless steels, high-chromium nickel alloys (eg Alloys 600 and 625), and HY80 and HYIOO low-alloy steels. HY steels and welding consumables, in particular, are vvidely used in Navy structures and weapon systems and have very low chromium content

4) The Task Group estimates that if the Cr(Vl) PEL is decreased to 0.5 µg/m^3, approximately 18,000 workers are likely to be affected. This estimate represents 17 Navy facilities, 5 private shipbuilders (Navy contractors) and 6 small marine businesses. One-third of these workers are - likely to be exposed to welding fumes.

5) The Task Group estimates there will be fewer workers affected if the Cr(VI) PEL is established at

the higher value of 5.0 µg/m³. The Navy Environmental Health Center database was used to estimate that as a percentage, 40% of the welders sampled would be affected at a PEL of 0.5 µg/m³ compared to 5% at a PEL of 5.0 µg/m³ or 10 µg/m³. The numbers for metal cleaning are 12% at the higher PEL% compared to 52% at the lowest PEL Therefore, the Task Group estimated that significantly fever workers (3,200) are likely to be affected if the Cr(VI) PEL is established at 5 µg/m³. This number is estimated to be approximately 600 workers if the PEL is set at a value of 10 µg/m³.

6) The estimated costs of compliance with the anticipated new OSHA Cr(VI) standard for three possible PEL levels are listed below. These estimates include one-time costs and annual costs for administrative functions, engineering controls, personal protective equipment, and reduced productivity.

- The estimated costs for compliance with the anticipated OSHA Cr(VI) standard for a PEL of 0.5 µg/m³ at Navy facilties include an initial, one-time cost of about $22,00,000 and annual costs of about $46,000,000 per year. The rests for compliance to this PEL for private shipyards are estimated to include an initial, one-time cost of about $9,000,000 and annual costs of nearlt $37,000,000 per year.

- The estimated costs for compliance with the anticipated OSHA Cr(VI) standard for a PEL of 5 µg/m³ at Navy facilities include an initial, one-time cost of about $3,000,000 and annual costs of about $5,000,000 per year. The costs for compliance to this PEL for private shipyards are estimated to include an initial, one-time cost of about $2,000,000 and annual costs of nearly $12,000,000 per year.

- The estimated costs for compliance with the anticipated OSHA Cr(VI) standard for a PEL of 10 µp/m³ at Navy facilities indude an initial, one-time cost of nearly $1,000,000 and annual costs of about $2,000,000 per year. This costs for compliance to this PEL for private shipyards are estimated to indude an initial, one-time cost of nearly $2,000,000 and annual rests of about $12,000,000 per year.

At this time, the study has not been able to address the Navy impact for Cr(VI) for all of the industries supplying equipment, materials and weapon systems to the Navy or the shipbuilding industry. All Navy contractors, suppliers and commercial shipyards have not yet been studied. Neither has the Task Group been able to estimate the cost impact of the new Mn limit or the anticipatede Ni limit It is expected that When these activities are included, the total cost impact to the Navy may double over the figures listed above.

7) Data on worker exposure to Cr(VI), gathered from published literature, the Navy Environmental Health Center database, controlled laboratory measurements, and worker sampling at shipyards show

- Historical Navy and industry worker exposure data for Cr(VI) cannot be used to estimate 8-hour exposures at the proposed PEL of 0.5 µg/m³ because these data were gathered using anaysis methods that were not sensitive to the anticipated new Cr(VI) concentrations.

  Mechanical deaning and painting operations often exceed the present ceiling PEL for Cr(VI) and respirator are already in use for a high percentage of cleaning, painting, thermal spray operations.

- Exposure levels to Cr(VI) for welders performing shielded metal arc welding (SMAW) of stainless steel and high-chromium, nickel alloys may be above 5 µg/m³ either with or without use of local exhaust ventilation.

- Exposure levels to Cr(VI) for workers in areas Were SMAW is being performed with hese materials also may be up to 5 µg/m^3.

- Exposure levels to Cr(Vl) for welders performing SMAW of HY80 and HYIOO Iow-alloy steels were, in some cases, at levels as high as *2 µg/m^3. This* is in spite of the fact that the chromuim levels in the welding electrodes used for these tests are low (0.1% Cr in E11018 and 0.3% Cr in E12018.) This area needs further study because of the widespread use of these steels by the Navy.

- Exposure levels to Cr(Vl) for welders performing gas metal arc welding (GMAW) of stainless steel and high-chromium, nickel alloys may be above *2 µg/m3* either with and without use of local exhaust ventilation.

- Exposure to Cr(Vl) for welders performing GMAW of HY80 and HYIOO Iow-alloy steels are likely to be above 0.25 µg/m^3 without use of local exhaust ventilation. Further testing is required to determine if local exhaust ventilation wiIl reduce exposure below this level.

- Exposure to Cr(Vl) for welders performing gas turgsten arc welding (GTAW) of stainless steels and high-chromium, nickel alloys are likely to be above 0.25 µg/m^3 without use of Iocal exhaust ventilation. Further testing is required to determine if Iocal exhaust ventilation will reduce exposure below this level.

- Further worker exposure sampling is needed. Many samples are required to confirm that exposure is below the anticipated new PEL's for these operations, due to the variability of this type of data.

8) The following technical impacts of the anticipated reduction of the Cr(VI) PEL on Navy facilities and public and private shipyards have been identified

- The use of materials and processes that contain or generate Cr(Vl) is expected to continue for the foreseeable future. These materials have been selected based on previous performance criteria of Navy weapon systems. Substitute rnaterials with equal or better performance characteristics have yet to be identified, tested, and approved for many Navy applications.

- It will be particularly difficult to controll exposure of workers performing painting, paint removal, welding, cutting, gouging, and grinding operations, as well as adjacent workers, in endosed and confined work areas in shops or on ships. In some cases, the limited size of openings in ships makes it difficult to accommodate the number of flexible ducts for air supply and exhaust systems when these operations are performed. Worker Cr(VI) sampling and experience with lead exposure suggests it will be difficult to reduce exposure below the proposed PEL levels for Cr(VI) in these situations.

- It is anticipated that reduction of the Cr(Vl) PEL will require the establishment of a large number of regulated areas in Navy facilities and in shipyards because work on chromiurn-bearing materials is perfomned throughout these facilities. For example, in the early stages of submarine construction, the entire vessel is likely to become a regulated area for Cr)VI). This will impact the scheduling of work and will result in reduced efficiency of not only the operations where Cr(VI) is involved, but adjacent operartions and personnel as well.

- Local exhaust ventilation, was not always completely effective in reducing welder exposure to Cr(VI) below 0.5 µg/m^3 for many shipyard operations or even below 5 µg/m^3 in some cases. In these situations, respiratory protection will be required, in addition to local exhaust ventilation.

- Data are not available to demonstrate that local exhaust till be completely effective for thermal cutting, gouging, and grinding operations.

- There will be a significant increase in the use of respiratory protection for two reasons 1) the need for protection for the additional operations where workers will be over exposed due to the reduction in the Cr(Vl) PEL; and *2) the need* to improve respiratory protection for those operations where it is presently used based on expected assigned protection factors. Many operations may require air-purifying respirators equippd with HEPA filters at a Cr(Vl) PEL of 5.0 μg/m^3 or 10 μg/nm^3. A Cr(Vl) PEL of 0.5 μg/m^3 would require respiratory protection with greater assigned protection factors.

9) *The* Task Group noticed a significant difference between the anticipatd OSHA PEL of 0.5 μg/m^3 and the American Conference of Govemmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV®) for chromates. More study by OSHA is recommended to resolve these differences.

10) Shipyard and laboratory worker exposure data show that some welding operations have the potential to exceed the new and anticipated limits for Ni and MN:

- SMAW and GMAW of stainless steels and nickel alloys have a high potential for exposure to Ni.. Shipyard worker exposure levels to Ni during GMAW of high-chromium nickel alloys in enclosed spaces ranged from 15 μg/m^3 to over 1 mg/m^3. Over 50 percent of these samples exceeded the anticipated limit of 100 μg/m^3. Welding with these processes in open spaces also has the potential for exposure above 100 μg/m^3, although none of the samples reported in this study exceeded this value.

- Worker exposure data indicate that SMAWand GMAWof stainless steels, carbon steels, and low-alloy steels (including HY80 and HY100) have the highest potential for Mn exposure.

11) Published literature shows that SMAW and GMAW of stainless steel, nickel alloys, carbon steels, and low-alloy steels have the potential to produce worker exposures to Ni and Mn that may exceed the new and anticipated exposure limits. While few shipyard and laboratory exposure samples exceeded the anticipated limits, there may be other operations (particularly those at high production rates or in enclosed and confined spaces) that were not sampled that have the potential for worker exposures above the anticipated limits for Ni, Mn, and total Cr.

12) The Task Group study described in this report outlines the scope of the technical and economic impact of the proposed reductions in Ni, Nn, and Cr(VI) exposure limits but has not resolved all of the questions that need to be answered. Future work is needed by the Navy and by the shipbuilding industry in the following areas

(a) Further review of the C(VI) health risk analysis is needed.

(b) The knowledge-base of worker exposures needs to be expanded. Many more worker exposure samples are needed to provide statistically valid characterizations of the operations, processes, and materials with potential exposure to Ni, Mn, Cr, and Cr(Vl). Further sampling is needed for.

- Materials with very low chromium contents, such as steel steel and HY-steels, and welding ccnsumbles for shielded metal arc welding (SMAW), flux cored arc welding (FCAW) and gas metal arc welding (GMAW).
- Operations performed in enclosed and confined spaces.
- Local exhaust ventilation.
- Wastes and residues, including fluxes and dusts.

c) The technical and economic impacts of the recent change in Mn and the anticipated change in Ni limits need to be determined.

(d) A research and development program is needed to establish methods to minimize airborne emision hazards during fabrication and repair in Navy facilities, shipyards or other industrial work sites. This program should address the following areas

- Development of a long range exposure reduction plan.
- Evaluation of new, less hazardous base and filler rnatetia!s.
- Evaluation of alternative processes with reduced emissions.
- Evaluation of improved engineering controls, collection and disposal techniques.
- Preparation of new requirements for shipyard use of these hazardous rnaterials.
- Expanded use of automotion/robnotics to reduce welder exposure.
- Development of design guidance requirements to minimize use of hazardous materials and maximize automation.
- Collaboration with Navy pollution prevention efforts.

Additional copies of this report can be obtained from the National Shipbuilding Research and Documentation Center:

http://www.nsnet.com/docctr/

Documentation Center
The University of Michigan
Transportation Research Institute
Marine Systems Division
2901 Baxter Road
Ann Arbor, MI 48109-2150

Phone: 734-763-2465
Fax: 734-936-1081
E-mail: Doc.Center@umich.edu